# TELESCOPE MAKING 43

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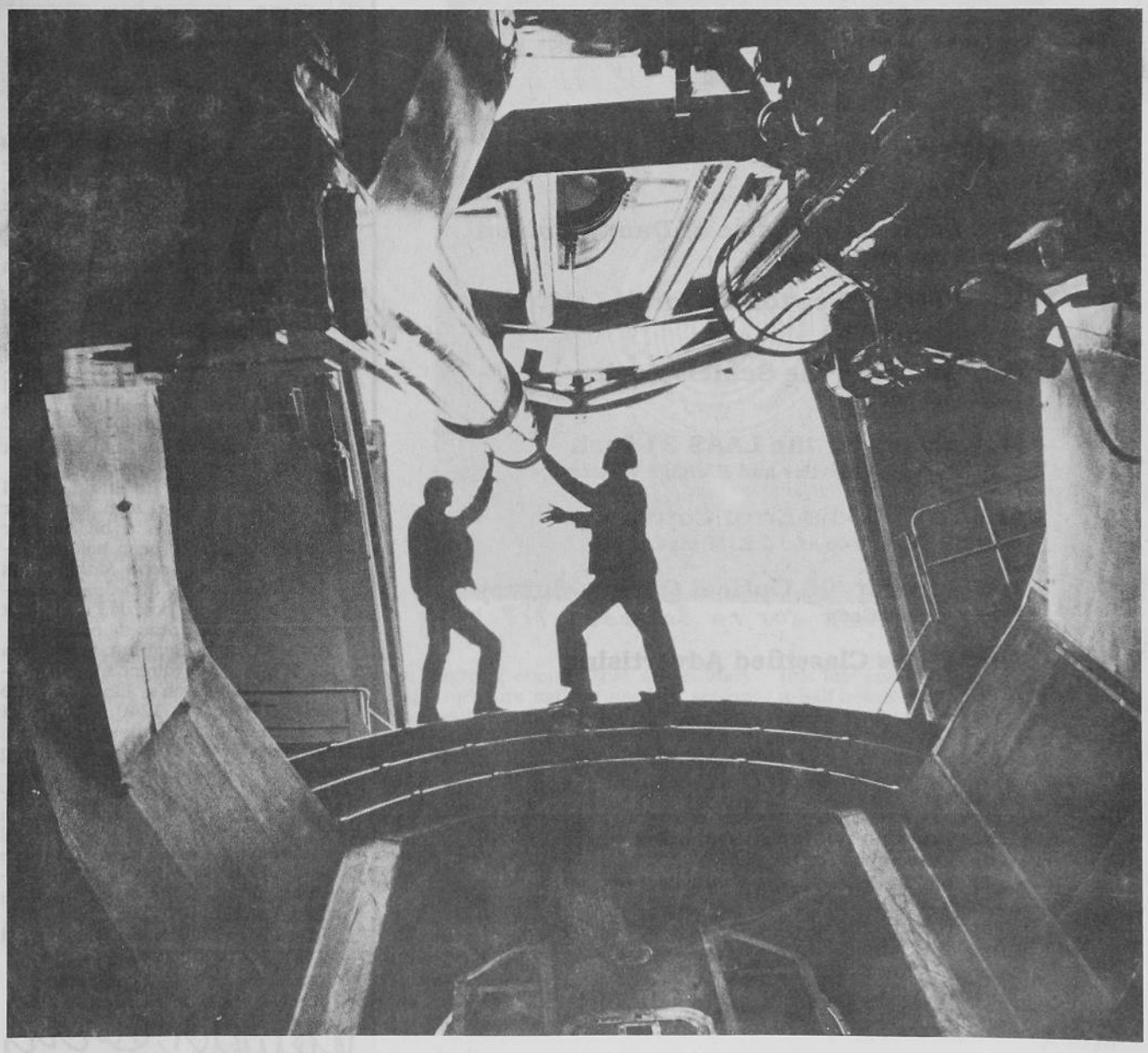
**The magazine *for*, *by*, and *about* telescope makers!** **Winter 1990/91**



# Telescope Making #43

The magazine *for*, *by*, and *about* telescope makers!

Editor: Richard Berry
Associate Editor: Peter Ceravolo

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**Cover**: Computers now control most professional telescopes, and with PCs becoming (relatively!) cheap, the computer-control revolution is moving to TMs. In this issue, you can see the progress as it happens, with the LAAS 31-inch telescope and Kanto and Munger's build-it-yourself PEC drive corrector. The cover commemorates the Soviet 6-meter at the Crimean Observatory, the world's first large computer-controlled alt-az telescope. Photo by S. Lidov.

## Editorial

In record time, another issue of *TM* is on its way to the printer. After the irksome delays in getting *TM#42* out, *TM#43* has been wonderfully quick. And if you've seen EARTH magazine, you'll probably agree that the big editorial, art, and production crunch in creating it was worth all the effort.

Special credit for this issue of *TM* goes to Tracy Staedter and Rhoda Sherwood. They have done yeo-person duty getting this issue flowed, proofed, and produced. Down the hall in the production department, Michelle Hankes has assumed responsibility for the production and filmwork necessary to bring *TM* to you.

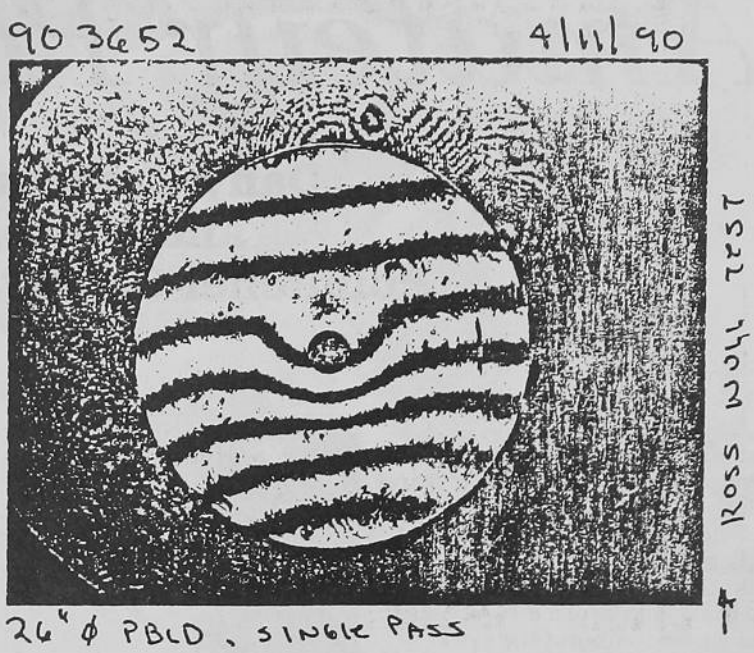
If you take loupe in hand, you'll soon spot a subtle sign of other changes. *TM*'s type is a bit sharper and crisper than it's been before. Until this issue, *Telescope Making* has been printed on a 300-d.p.i. laser-printer, pasted to boards, and shot conventionally in a process camera.

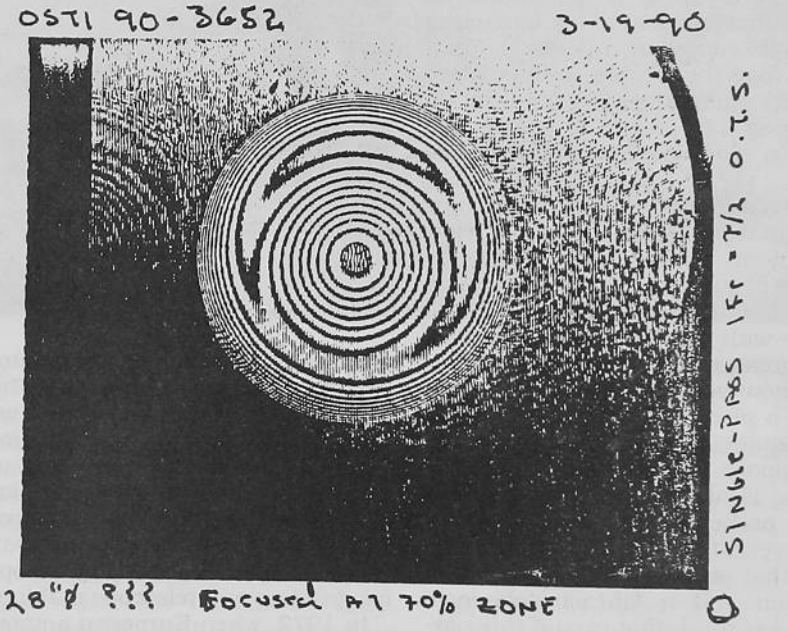
That's no more. Beginning with this issue, TM is going direct to film output from Kalmbach's Linotron 300 phototypesetter at 1240 d.p.i. Not only is the quality of the type better, but we now have the option of putting halftone images directly into our pages from TIFF-formatted files and other digital formats. As soon as we've got a handle on the formats we can use, I'll let you know. As you can see from the stories in this issue, more authors today have access to drafting programs than ever before.

I'll be at the Winter Star Party and Riverside. See you there...

Richard E. Berry

# Letters




**Ross Null Practical, Reliable**

Richard/ After reading Mr. Vranjican's comments on Stoltzman and Ceravolo's explanation of the Ross null test, I feel moved to throw in my two cents worth. Working as an engineer in the optical fabrication industry keeps me on the lookout for methods of accurately testing a wide variety of optical components and systems. Often, the choice of which test to use is influenced by the factors of cost, time, and practicality of construction, i.e., the same factors that influence the amateur, only more so.

I first became seriously interested in the Ross test about a month ago, when my employer handed me a 26-inch diameter mirror of unknown asphericity and surface quality. We wanted to know whether or not the optic could have any potential use as a piece of test equipment; i.e., was it a good, smooth paraboloid? To find out, I computed a Ross Null lens based on the method of Stoltzman and Ceravolo for use with our laser unequal path interferometers, which use a helium-neon laser source operating at 633 nanometers. The pictures depict the results of this test.

The first test was done with the interferometer placed at the radius of the 70 percent zone, without the Ross lens in place. The resulting interferogram indicated that the amount of correction present was the amount that a paraboloid of the measured radius and diameter should have.

The second test was done with the Ross Null test lens in place. The lens was computed according to information in the *TM* article, and optimized very slightly on a computer (using a lens-design program available for $250) to account for variations in glass thickness and test wavelength. With the null lens in place, the overall surface figure is well enough nulled to reveal the only significant, localized defect to be a central hole occupying the central 25% of the aperture.

As I mentioned before, I have had many opportunities to set up and evaluate a wide variety of null tests in the laboratory. In every respect, I found the Ross null to be one of the simplest, least expensive, and most practical tests that I have implemented. The cost of a small, plano-convex lens, when compared against the cost and sheer size of a full-aperture flat, is insignificant. The lens surfaces need only be smooth over the intended use aperture; variations in center thickness and wedge are easily compensated for in the design and alignment of the test.

The source-to-lens distance and the lens-to-mirror distance were found to be forgiving enough that an ordinary tape measure can be used to set up the test! Changing both of these distances (if you change one, you must change the other) appeared to have no detectable effect on the quality of the null, even though the source-to-lens distance (theoretically the most sensitive to change) was varied over a range exceeding one quarter of an inch, a tolerance that anyone can expect to hold using only the simplest of equipment. The test alignment was found to be sensitive to the presence of tilt errors (coma present) but relatively insensitive to decenter (maybe some slight astigmatism.) Overall, the time to set up, align, and evaluate this test amounted to about one-and-a-half hours of effort.

Mr. Vranjican goes on to describe methods which he feels are more suitable for amateur use, and yet each of these has problems that, seen through the eyes of experience, present even an accomplished amateur with difficulties that the Ross test minimizes or avoids altogether.

The two-lens Offner null that he mentions, while giving an excellent null even for large, fast mirrors, requires a precisely machined cell to hold the components in line. Most amateurs can neither afford nor make such a cell. Those who can probably

*continued on page 44...*

# Amateur Paradise

## Dany Cardöen and the Puimichel Observatory

Imagine a place where the sun shines more than 200 days a year. Imagine a place where butterflies gather nectar of orchids. Imagine a hill where lavender fields stretch as far as the horizon. Perhaps you think that such a place could exist in many places around the world.

But now imagine that in this place everything is peaceful and quiet. Imagine that many languages are spoken by many people. Imagine that the people in this place respect each other. In your mind, you may have begun to realize that such a place might just be a trifle rare.

What's more, now stretch your imagination and suppose that astronomy is the common passion of the people. Imagine here you can meet friends who do not hesitate to share with you their secrets for taking great astrophotographs. Possibly, now you have begun to think such a place is quite exceptional or even quite impossible.

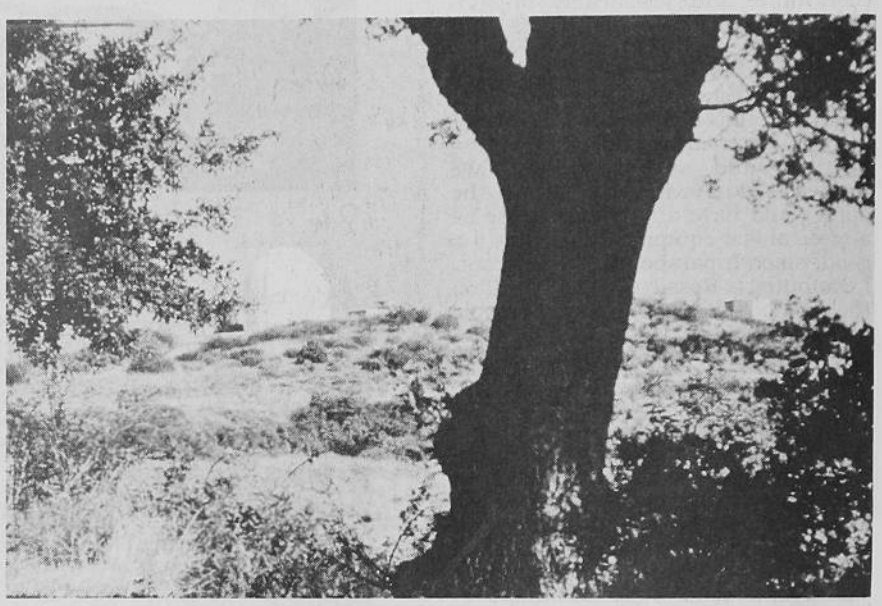
Suppose that I add that here the seeing is almost always one arcsecond or better, and several nights each year it reaches 0.2 arcseconds. And that on this hill is a 16-inch, a 20-inch and a 42-inch telescope! You now think that even if this paradise exists, it is not a place you could ever hope to visit.

But you would be wrong. This paradise exists and you can live in it. You can use any of these telescopes for whatever you want, even for visual observations, and even if it's only for your own pleasure.

Yes, I can testify that this amateur astronomer's paradise is a reality. I spent two days in Puimichel in France, and my life cannot again be the same.

### "I Have a Dream..."

It is with these words that Dany Cardoen, the ever-smiling and jovial creator of Puimichel Observatory begins to tell me of its birth. When he was 40 years old, Dany was about to discover astronomy. Born in the Flemish area of Belgium, Dany grew up under ever-gray skies of the "flat county" where astronomy rhymed with theory. But Dany early on became interested in optical grinding and telescope making.



*Quietly nestled in the countryside are the dome of Dany Cardöen's 1-meter telescope (left) and the shelter for 20-incher (at right).*

In 1972, when European amateur telescopes were seldom bigger than 8 inches, Dany built his first big instrument: a German mounted 16-inch f/5 Newtonian. This "impossible" telescope would soon become the beginning of an incredible adventure. Because he had no particular difficulty building this first instrument, Dany dreamed.

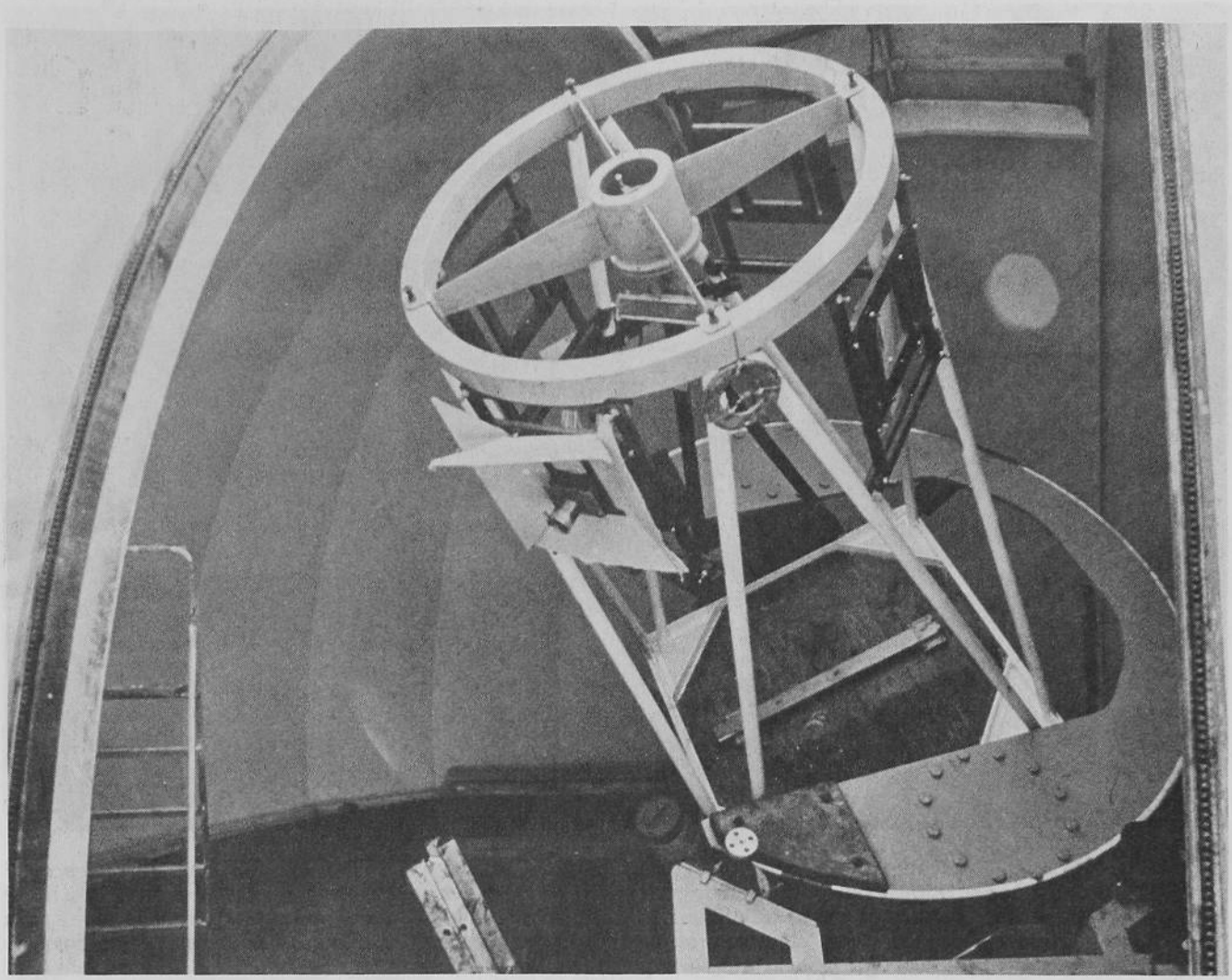
"I had a dream, a very big telescope in an ideal site, and there, amateur astronomers of the world could come and use it for their work or their pleasure," says Dany, with passion in his voice.

By 1979, Dany's dream had grown, and he decided to build a one-meter telescope. But such an instrument needs a near-perfect sky.

### The Quest for a Perfect Sky

Location: the south of France, Saint-Michel-l'Observatoire, in the Haute Provence area. Here we find the Observatory de Haute Provence, a professional observatory with 1.2-meter, 1.52-meter, and 1.93-meter telescopes, some of the biggest in French territory. The seeing is almost perfect. Professional investigations show a very high-quality sky. The landscape is marvelous, full of gentleness, with colorful flora and amazing animals for a European country.

With his wife, painter Arlette Steenmans, Dany decides to leave his roots. Goodbye Belgium, hello



*Through the wide dome slot we have our first glimpse of the 1-meter reflector and its massive split-ring equatorial mounting.*

France! From 1979 to 1981, Dany and Arlette test the sky near Saint-Michel-l'Observatoire. Finally they find a small village, Puimichel, at 2000 feet altitude. With only 100 inhabitants, Puimichel is in a quiet place, protected against the mistral wind by a hill. Dany and Arlette find an old barn. In 1982, they decide to set themselves up here.

The next step is not observing, but restoring the barn. To house the amateurs Dany hopes to attract, the barn needs bedrooms and a kitchen to prepare meals for them.

Dany's idea is to install a powerful telescope to attract amateurs. So he decides to move his 16-inch from Belgium to Puimichel. He builds his first equatorial fork mount for it, and he founds the "Newton 406 Association." As word of the telescope spreads, amateur astronomers flood in from Belgium, Germany, and Switzerland. Dany also builds a coelestat to put in place its own 102mm coronograph with an H-alpha filter to observe solar prominences. Paradise begins to grow in Puimichel.

**Patience, Always Patience**

To realize his childhood dream, Dany would wait ten years—ten years filled with patience, hope, and also discouragement. Grinding a one-meter mirror is more than an adventure for a lone amateur—it is close to impossible. Dany prudently decided to build a 20-inch telescope with a f/3.8 ratio first, as an experiment, because he realized that his one-meter instrument could not have an f/5 focal ratio and fit in a small dome.

This first attempt at a fast primary met with real success: the 20-inch mirror reached 1/37-wave precision. A completely open and very light tube and a compact fork mount complete the instrument.

The time had come for Dany to build his monster.

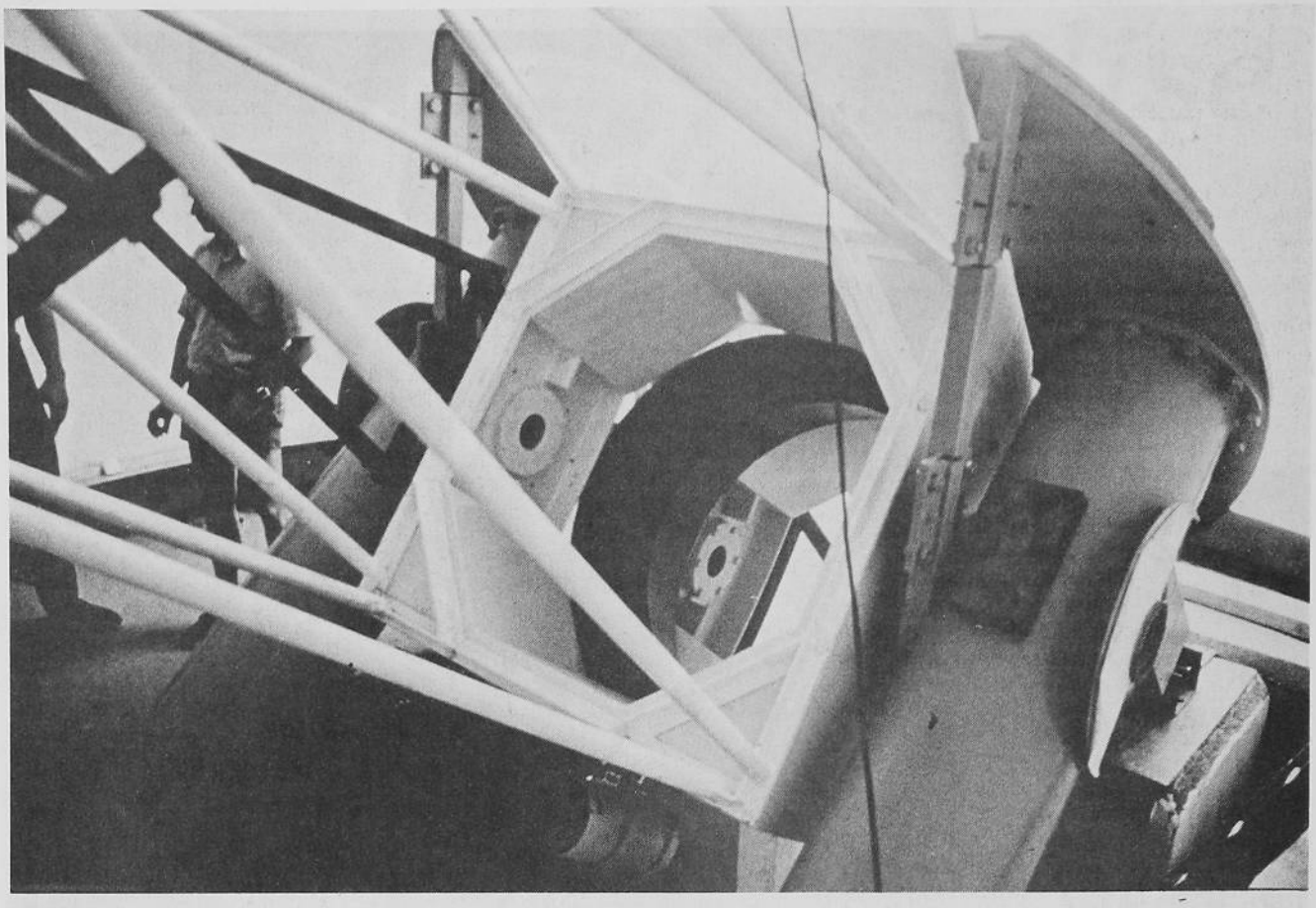
**The Fabulous Challenge**

When you want to grind a one-meter telescope, you have first to find a mirror blank. The well-known German amateur astronomer Dr. Hans Verhenberg and the Swiss astrophotographer Gerhardt Klaus helped Dany locate one in Arizona. The owner of the blank, Mike Simmons, agreed to sell it. The blank had been used to test other telescope mirrors.

When Dany and Arlette opened the box that came from overseas, what a surprise! They found 1,100 pounds of chocolate. Happily, a few week later the blank really arrived in Puimichel.

Dany put it on a special support and began to grind it face up on an 18-point flotation system on the grinding machine he had specifically built in his workshop in the lower floor of the restored barn.

But one morning, catastrophe struck: in the middle of the night the



*Is it really an amateur telescope? The answer is "yes," and it's there for amateur astronomers from around the world to use and enjoy.*

mirror split in two. Everyone was very disappointed, and Dany even considered ending construction.

But such a dream cannot die, and Dany finally decided to continue. With the help of Peter Aniol and Lenhart Dahlmarh (a Swedish amateur astronomer) and support from his aunts Lydie and Betty Cardoen, Dany bought a new blank. This time, Schott provided a Zerodur blank cast to the correct curve, and Dany ground and polished once again. Jean Texereau, the well-known French astronomical optician, gave Dany advice on working the large mirror.

During this time, Dany's brother got involved. He owned a factory in Belgium, and he had the giant horseshoe mount weighing 1.2 tons fabricated from Dany's drawings. Meanwhile, a Dutch group of amateurs helped Dany build the 6.5-meter dome.

1987 was an historic year. The mirror was finally completed. And, in spite of its enormous diameter, the mirror came out to 1/25-wave. The 406mm secondary mirror was also ground, large enough to provide a wide fully illuminated field. The Observatory de Haute Provence aluminized them.

During 1988, Dany constructed the Serrurier truss tube and—with some difficulty—installed the horseshoe mount in the dome. At long last the first pictures were taken. They turn out as well as, or perhaps even a bit better than, those obtained with equivalent professional instruments.

The challenge is won, the dream is alive.

**Puimichel Today**

September 1989: I have decided to experience paradise. I contact Dany Cardoen; the phone call is like a dream. "Hello, Mr. Cardoen, is it possible to come in to Puimichel to observe with the one-meter telescope next week?

"Certainly, he tells me, "no problem. There's nothing scheduled on it. I'll reserve your place."

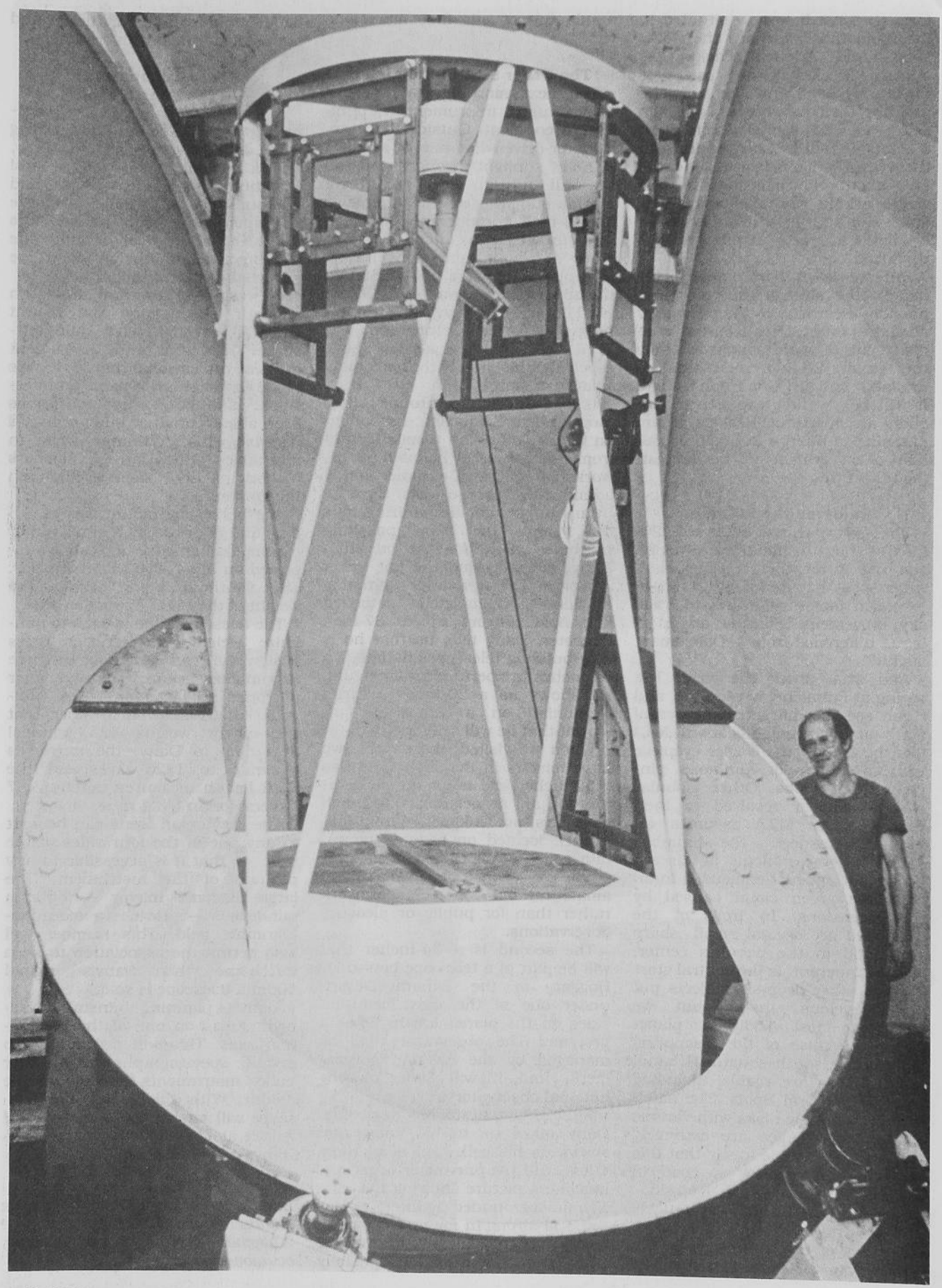
Access to paradise seems too easy, don't you think? In fact, I was lucky. Dany later told me that my reservation was due to exceptional circumstances. During vacation season and every weekend, the observatory accommodates as many as 20 to 30 persons. The most popular times are New Moon weekends.

At once, I contact my old friend Germane Delattre, who immediately cancels everything else previously planned to come with me. After a day-long car trip from Normandy to Haute provence, we try to locate Puimichel. Finding paradise is difficult because the observatory is not well marked. Tranquillity must be protected from crowds.

Arlette and Dany welcome us. Their Flemish accent sounds marvelous to our ears. We are not alone in the barn. Two German amateurs, Herr Lille and Herr Dewolf, are spending the week here with their own instruments. An amateur from England, a Mr. Ferris, takes vacations here and has come to make time plots of stellar occultations.

We are introduced to Patrick Legrange who is employed by the Association to guide telescope users who are not yet skilled. Dany explains to us that the president of the Newton 406 Association is Max Brunel, the mayor of Puimichel, who completely supports Dany's project.

The dining room is shared by everyone and can accommodate up to



forty persons. It is now situated in the room that was once the workshop. And Arlette's cooking is superb. Mealtimes are privileged times, when Dany and Arlette describe their adventures, or when Dany unveils some astronomical techniques that he has gleaned over the years. Other times Arlette will talk about the paintings on the walls. Arlette works in a realistic style. Her still-life works hang side by side with the portraits she has produced.

But we learn bad news during dinner: the electric generator that provides electricity to the one-meter dome has failed. Because Dany cannot repair it until tomorrow, only the "small" 20-inch instrument is available tonight. But I don't mind! It will be my first experience with such an aperture. Besides, I am planning to build a 20-inch Dobsonian of my own; it will be interesting to test this one.

### Enjoying the 20-Inch

The first surprise with the 20-inch is how it handles. Although you use it just like a Dobsonian, when you let go of it, a high-precision motor continues to track sky movement. That is an enormous difference from a Dobsonian, isn't it?

And what about the view? The seeing at Puimichel is very fine, and I can see the diffraction figures of stars at high magnification! M13 fills the field of the Nagler eyepiece with a shower of luminous pinpoints, not blobs. Other globular clusters appear resolved to their very centers. M27 assumes an interesting aspect: the dumbbell shape become difficult to discern because it appears embedded in an elongated green cloud caused by the extensions. In front of the Dumbbell are several small, sharp stars and in the nebula's center, readily apparent, is the central star!

Many other deep-sky objects put on marvelous shows, but we remember most vividly the planet Jupiter because of the disappearance of the south equatorial band. Many details are visible, including some White Oral Spots. The satellites present true disks with various colors. The images are extremely stable. It is possible to say that this 20-inch telescope is as good in planetary observing as in deep sky.

These observations were quickly done during two hours just before the onset of big white clouds. We returned to the barn to sleep, our minds full of our first marvelous views.

### The Other Side of Puimichel

The next morning, we spied a most unusual instrument in Puimichel: a coelestat. Outside the barn, a motor-driven flat mirror sends a beam of sunlight through a hole in the wall and into the library where a table supports a 4-inch refractor and 4-inch coronograph equipped with an H-alpha filter. You can study sunspots using the refractor to project an image of the Sun to the opposite white wall of the darkened library, or observe solar prominences with the coronograph. The Sun always puts on a good show, especially this year with the coming solar maximum.

Dany shows us around. Two months before our visit, he bought an old building half a mile distant from the barn and has set up his workshop there. Germane and I admire the machine tools, the vacuum chamber for aluminizing mirrors, and the two polishing machines, including the one that Dany used to grind the one-meter mirror. The second grinding machine is completely motorized and hold mirrors up to 37-inch diameter. Dany tells us that he is now building telescopes as large as 34 inches in aperture for amateurs. He shows us a 20-inch Serrurier Newtonian on a motorized fork mount that he will sell for $25,000.

When we visited, there were two large mirrors in the shop. One was a 32-incher and is for the observatory of an association of French amateurs some kilometers from Puimichel, located on a small mountain called Mont Chiran. This telescope will also be available to amateurs, but for technical work rather than for public or pleasure observations.

The second is a 34-incher that will be part of a telescope bound for Hoggar, in the Sahara Desert, under one of the most beautiful skies on the planet Earth. What a program! The observatory will be managed by the Algerian government, and it will serve as the national observatory.

After this visit to his workshop. Dany takes us to his home and shows us his collection of pictures taken with the one-meter telescope. Imagine a picture showing the Ring Nebula surrounded by fifteen galaxies! Still strong in my memory is an incredibly colorful picture of the Orion nebula and some exquisitely detailed photographs of Jupiter and of the Moon riffled with craterlets.

### Close Encounters of the Fourth Kind

In the afternoon, we visit the one-meter telescope dome. The dazzling white dome is visible from far away, and it's a big dome—6.5 meters! But the best is inside: we enter and find ourselves on the floor below the instrument. We climb the ladder to the observation floor around the instrument—and that's when we receive the biggest shock.

We cannot believe that this is an amateur observatory: the mount looks like the 5-meter Hale telescope. The design of the instrument looks so professional that we realize Dany Cardoen is as much a professional as he is an amateur. He has been able to produce such a marvel because his training was in mechanics. But Dany remembers his origins and has not forgotten the amateurs.

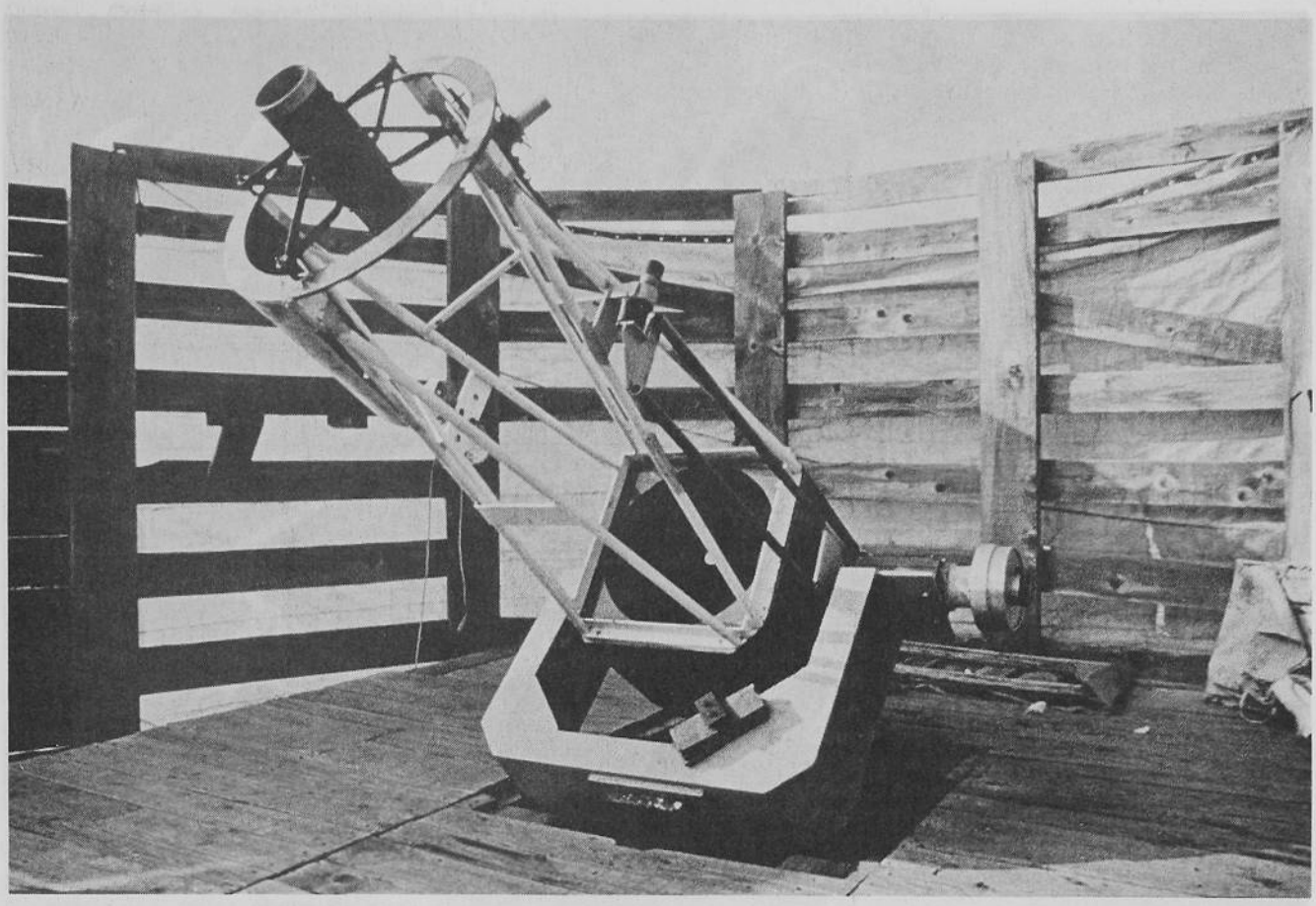
The horseshoe mount weighs 1.5 tons and is driven by a small motor turning its immense horseshoe supported on a massive concrete pillar. The southern pillar carries the weight of the Right Ascension axis.

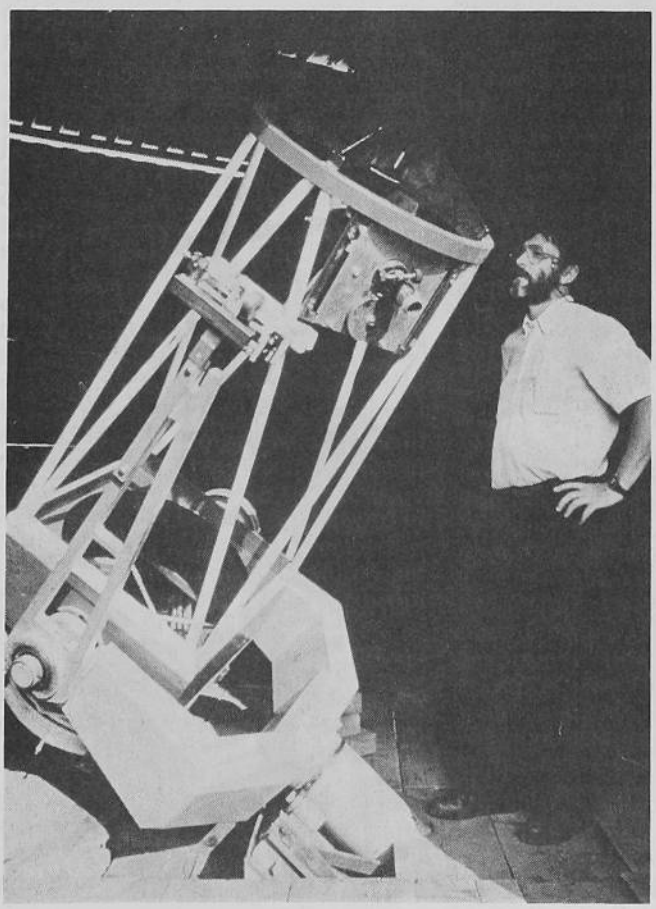
The telescope tube is open to minimize weight. A Serrurier truss design has been chosen for the tube to minimize flexure. The one-meter mirror is, in fact, actually a 1.06-meter instrument. Remember that the mirror weighs 425 pounds! According to Dany, the mirror is accurate to 1/25-wave, and the focal length measures exactly 3.57 meters, for an f/3.4 ratio.

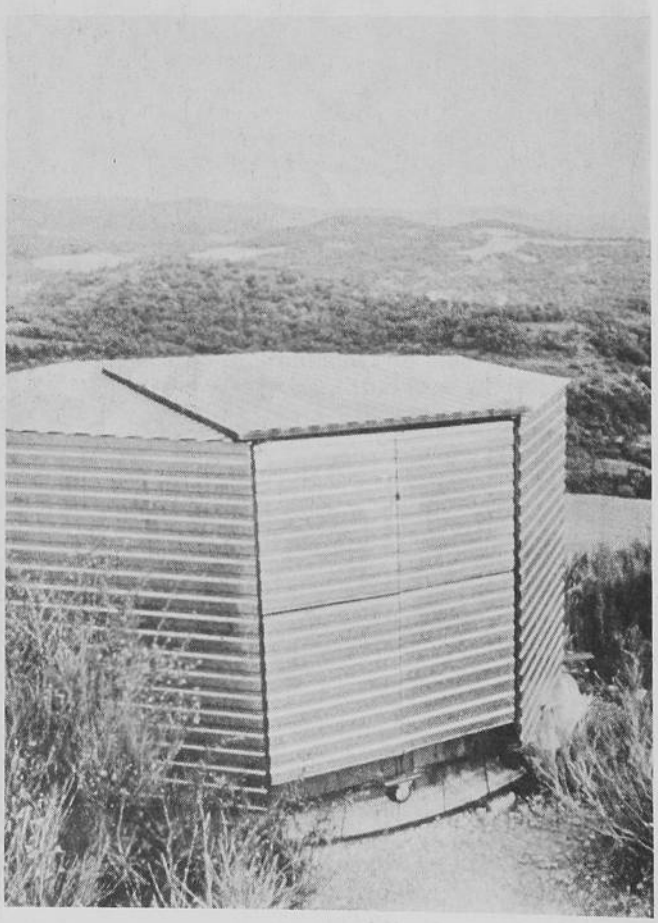
The Newtonian focus can be sent to any one of the four sides of the tube, so that it is accessible in any position of the instrument. The large diagonal mirror — 406mm minor-axis — provides a wide photographic field. This number will also permit the association to keep its name when Dany's original 406mm telescope is sold.

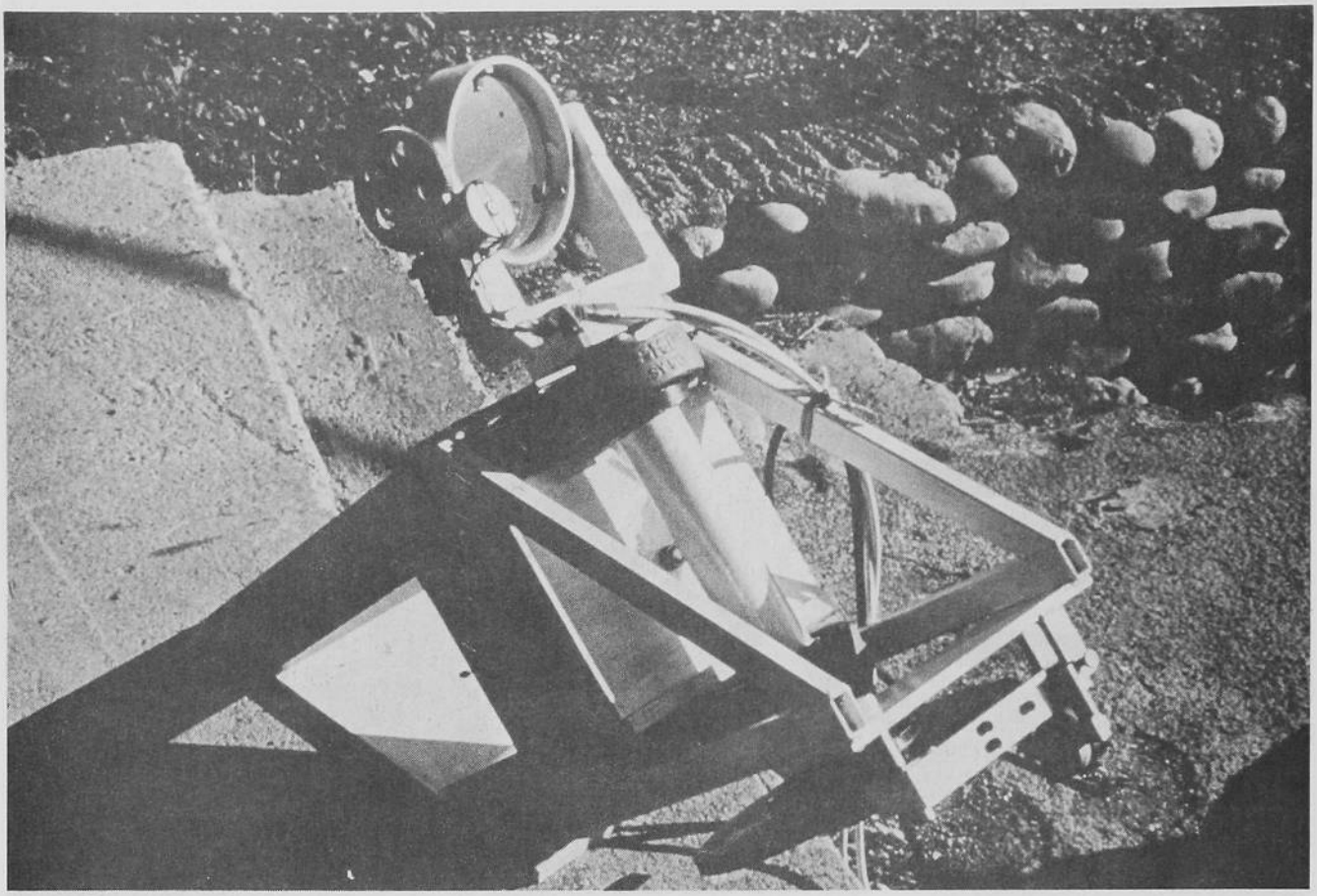
Dany is planning to install a Nasmyth focus on one of the declination axes. This will permit him to install spectrographs and other bulky instruments directly on the mount. With this focus, the telescope will have a 12.72-meter focal length at f/12! CCD imaging, says Dany, is coming soon!

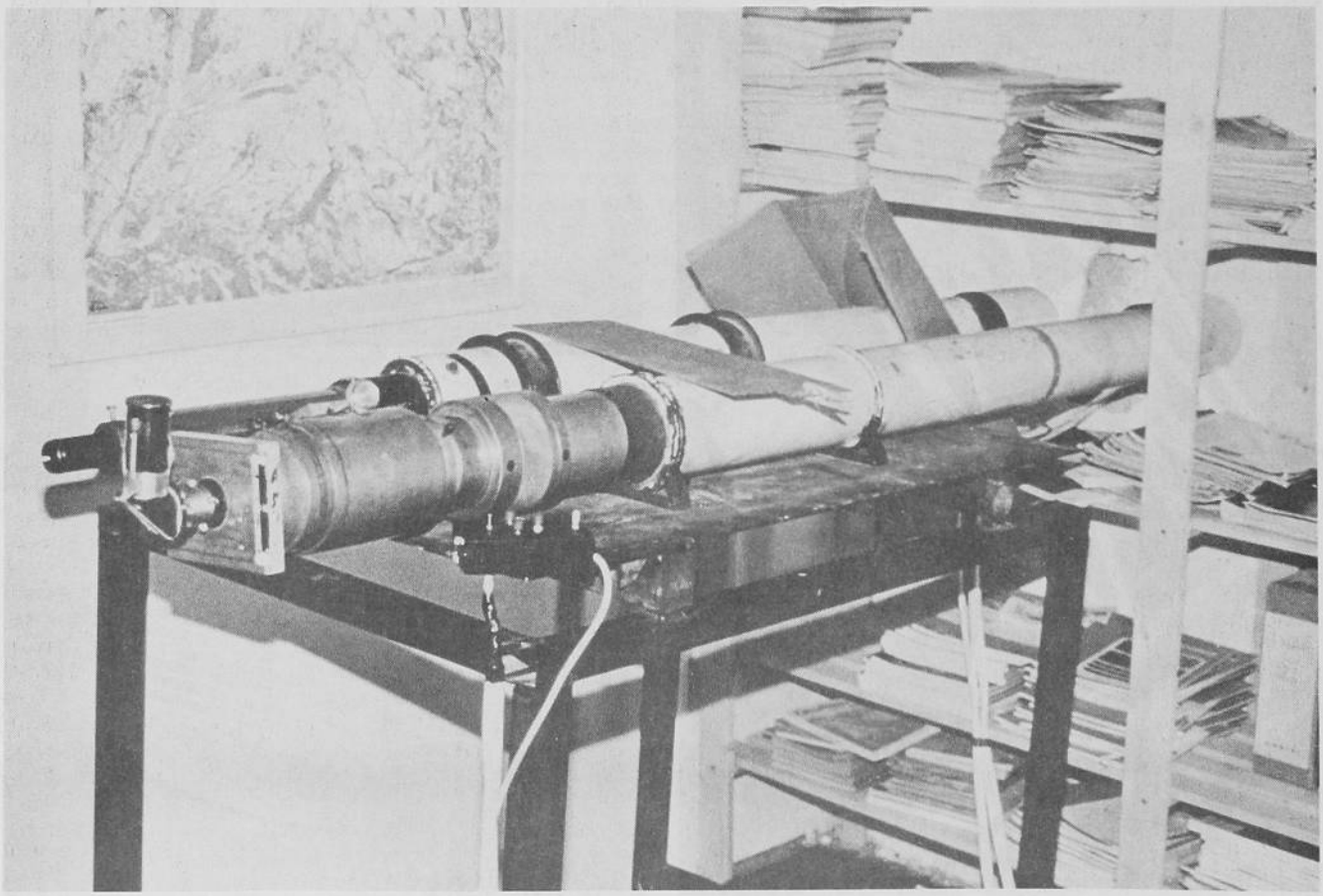
*Dany's original 406mm telescope stands in a simple wind shelter. The 20-incher resides in a rotating, octagonal observatory.*



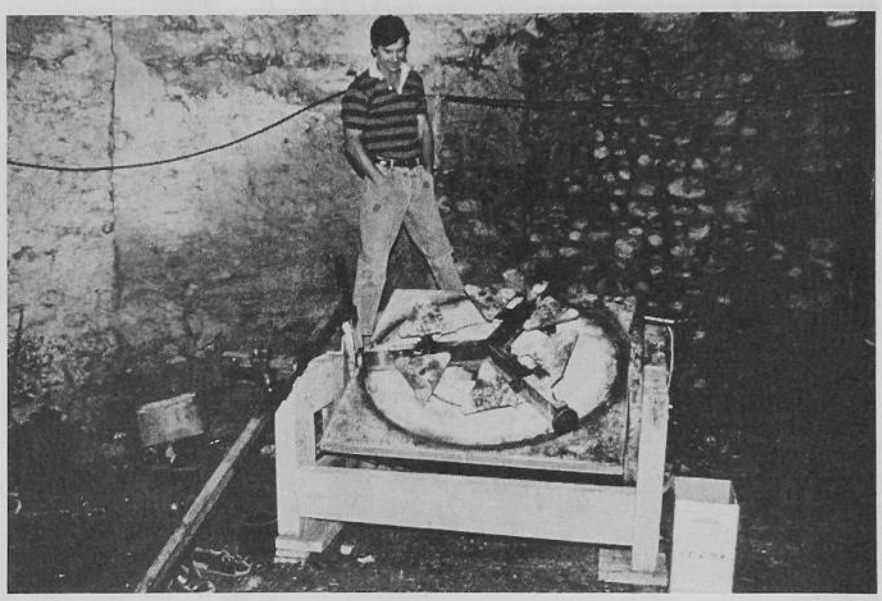








*Danny Cardöen (center), author Christian Legrand (right), and Jerome Delattre at the office of the "Newton 406" association office.*



*Dany Cardöen contemplates the large grinding machine with its flotation cell that he used when he ground the 1-meter mirror.*

**One Life's Experience**

But during the second night, it is time for Germane and me to experience one-meter viewing. The generator has been repaired and nothing threatens to reduce our happiness and our enthusiasm. But alas—at sunset clouds come and there is no wind to push them away. We wait all night until, at four in the morning, a large hole in the clouds appears. In a single half-hour period we can have a quick view of the Moon, Jupiter and Orion nebula.

First surprise: As with the 20-inch, you pull the telescope by hand. Big coordinate circles are ready to help you if you need them. I could never imagine that one day I would be pulling such a delightful and smooth-moving instrument with my hand. The telescope feels almost a like a friend whom you touch on the shoulder.

What to say? It is like a dream. Observing the Moon, it seems to us that we are in an Apollo mission orbiting a few miles above its surface. Among countless details seen through the eyepiece, I especially remember Rima Birt 2. It is a very small line near Rima Birt 1, close to the Straight Wall. Rima Birt 2 is just visible on the best photographic lunar atlases. Here, in front of our eyepiece, it is evident. The Moon with a one-meter? What a showpiece!

I could never forget viewing the core of M42. The nebula overflows the eyepiece field. Dead center, in the billows of the luminous, fluffy cloud, the Trapezium stars nestle. We easily spot two faint members among the six bright, easy one. All this was done with the Moon shining only a few tens of degrees away. I cannot imagine what it could be during New Moon.

And finally, we come to Jupiter, even more detailed than it was in the 20-inch. It is a luxury of details: bands, clouds, belts, and spots were far too numerous to be drawn. Here, too, the exceptional quality of the sky adds to a marvellous instrument, exceeding everything I have seen before.

*The coelostat mirror outside the barn follows the Sun across the sky; inside a refractor and coronagraph ancourage solar studies.*

**Back to the Future**

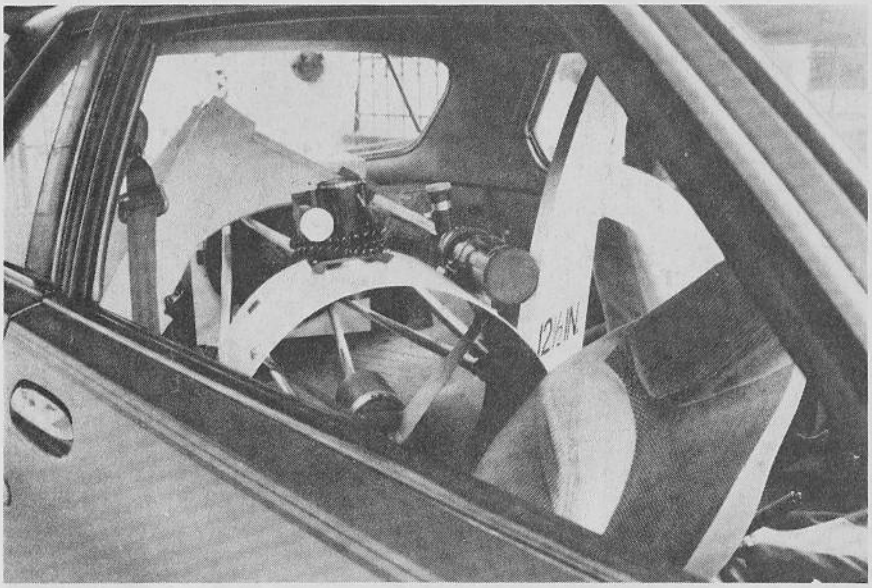
Despite the shortness of the moment, Germane and I are conscious that we have lived a great moment in our lives. We already know that we will come back to Puimichel. Dany is so different and Arlette so pleasant. We want to meet again the European amateur astronomers whom we met, and maybe also meet those of you who are reading this article.

So perhaps we will meet. Germane and I are sure to come back to Puimichel to see the Universe again. But this time we will prepare our observations. No celestial tourism. We will plan amazing pictures. Or we will track down small planetary nebulae. Or we will... but it does not matter! Everything is permitted in the amateur astronomer's paradise.

Christian D. Legrand
260 route de la Bellevue
76160 Preau
France

*Note: For a complete day, including three meals, bedroom, and use of the observatory, the price is 200 French francs, or about $33 US. Write to: Dany Cardöen, Observatoire de Puimichel, La Remise, 04200 Puimichel, France.*

# A Split-Ring Newtonian for 9 Degrees Latitude



*Although the largest telescope in Panama, Luis Harris's split-ring fits in the trunk and back seat of a compact car.*

One of the main considerations for an amateur telescope maker planning a large telescope is the weight and bulk of the finished telescope. If the telescope becomes too large and heavy, transporting the telescope to a good viewing site leads to frustration and back pain.

A good design must allow the amateur to set up and use a telescope with a 10-inch to 16-inch aperture in a matter of 15 to 20 minutes. When the set up is quick, observing remains a pleasant experience.

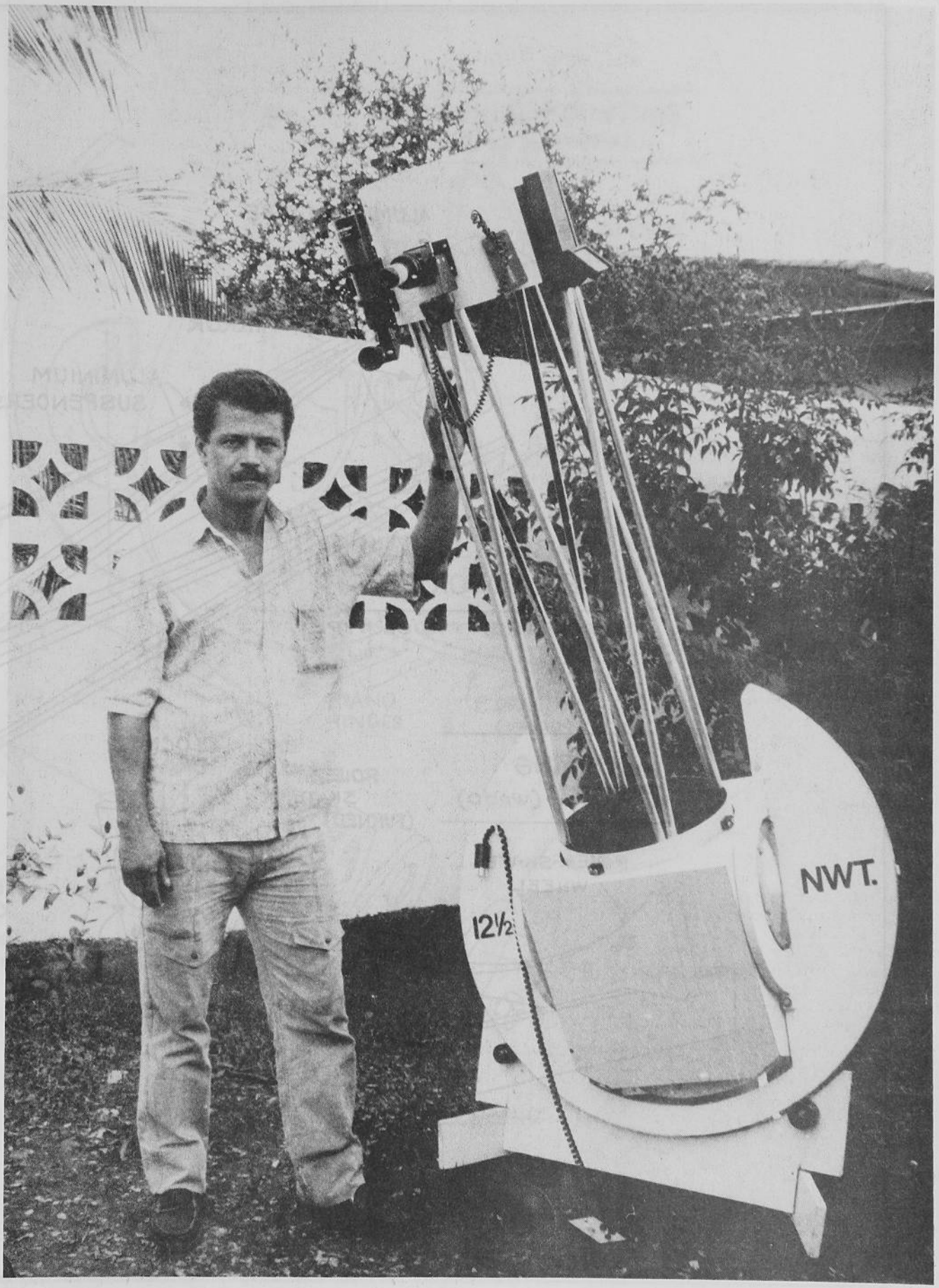
My design is similar to a 10-inch f/5.6 reflector built by Mr. Joe Pearson. Compare his design with David Moerke's 12.5-inch split-ring design in *TM#39*, Paul Mahaney's massive 18-incher in *TM#37*, and Gary Walker's 14-inch pictured in *TM#31*. Pearson's story (March 1986, *S&T*) had photos and drawings, and included step-by-step instructions and assembly drawings. I was so impressed with Pearson's design that it became my dream telescope, and I vowed I would build it when I was able to get all the necessary components together.

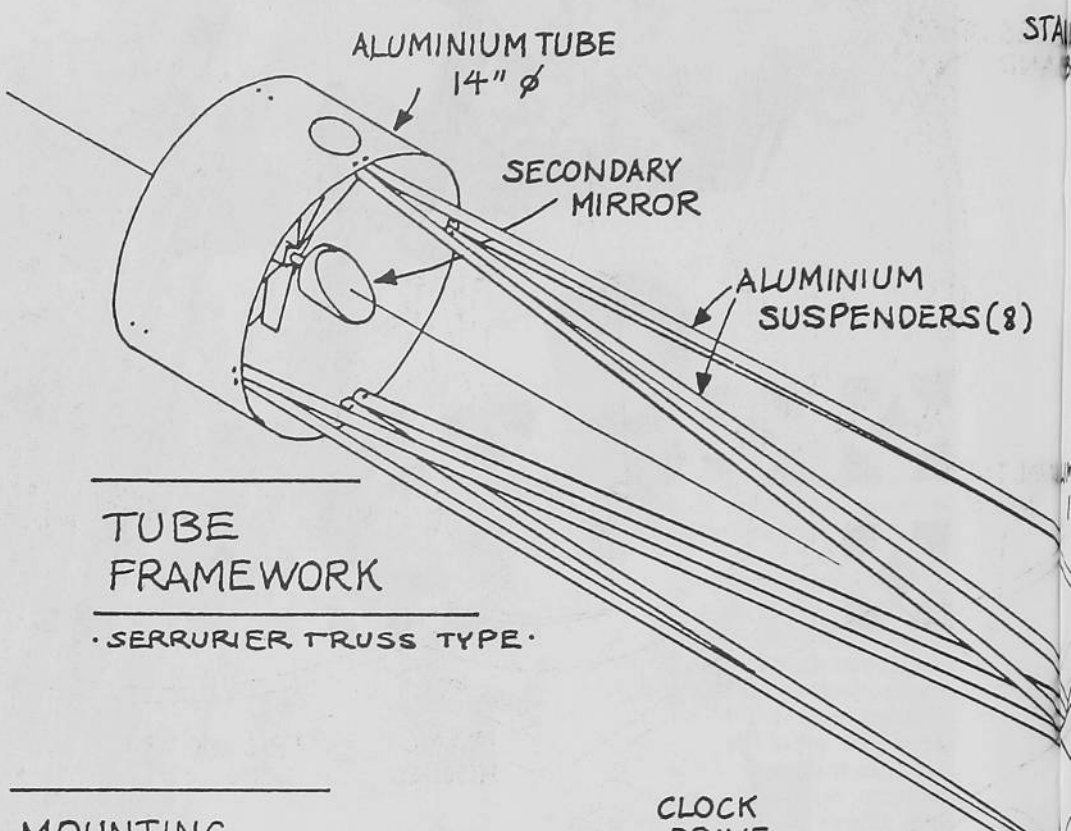
I was most fortunate in being offered a package deal of just about everything I needed. Ronald Benninghoff, a member of the local Panama Canal Astronomy Club, had ordered a 12.5-inch f/6 mirror from Enterprise Optics with the intention of building a standard Dobsonian-mount reflecting telescope. I immediately began the construction of my "dream scope" with a slightly modified Novak mirror cell, a Novak spider, diagonal mirror assembly and focuser, plus some University Plossl eyepieces, based on Pearson's design. I also found inspiration in the chapters on split-ring equatorials in Amateur Telescope Making - Book One.

Like Mr. Pearson, I built the Serrurier Truss tube. This made the finished telescope lighter, without giving up the rigid design necessary for retaining good optical alignment. The horseshoe type mounting, similar to that of the 200-inch giant on Palomar Mountain and the 4-meter Mayall Telescope on Kitt Peak, provide excellent weight distribution and rock-solid stability. This is because the weight is centered directly over the middle of the polar disk.

I redesigned the mounting for our 9-degree latitude. As you can see from the photos, the south end of the polar axis is nearly as high as the center of the horseshoe. This point bears only a very light load, and the drive roller and idler bear nearly all the weight of the telescope.

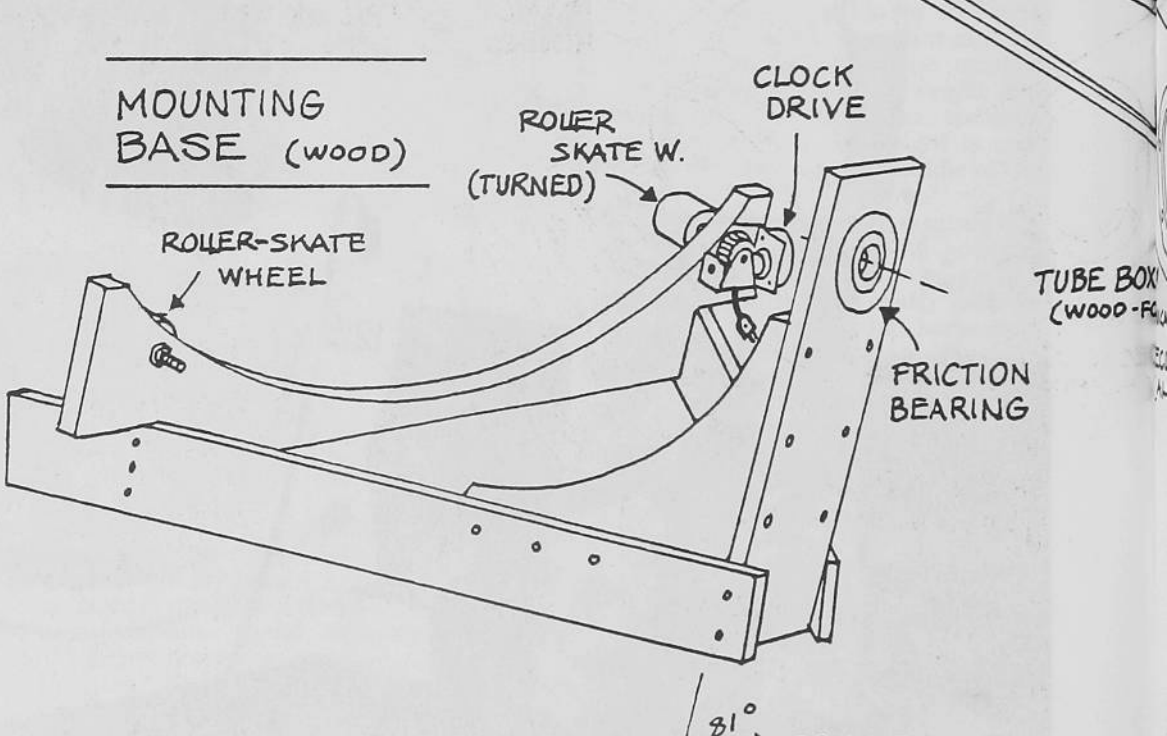
I agree with Pearson's recommendations about building and assembling a telescope. Start with the front tube assembly, which contains the spider, diagonal mirror, focuser mount, finder, and so forth. Construct the rear components which house the primary mirror next. Then build the tube-holder

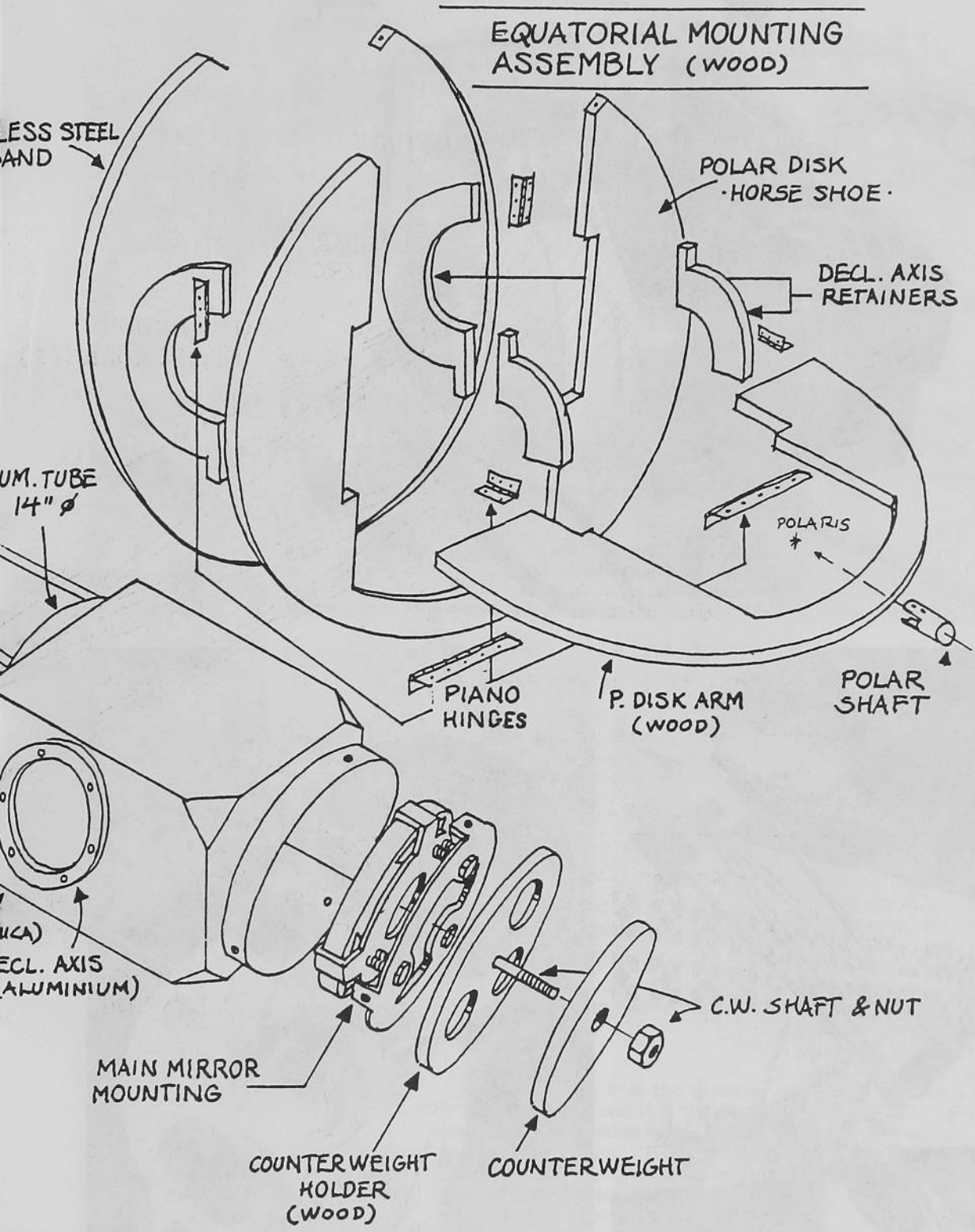

NWT.
12½




## TUBE FRAMEWORK

· SERRURIER TRUSS TYPE ·




EQUATORIAL MOUNTING
ASSEMBLY (WOOD)
LESS STEEL
AND
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·HORSE SHOE·
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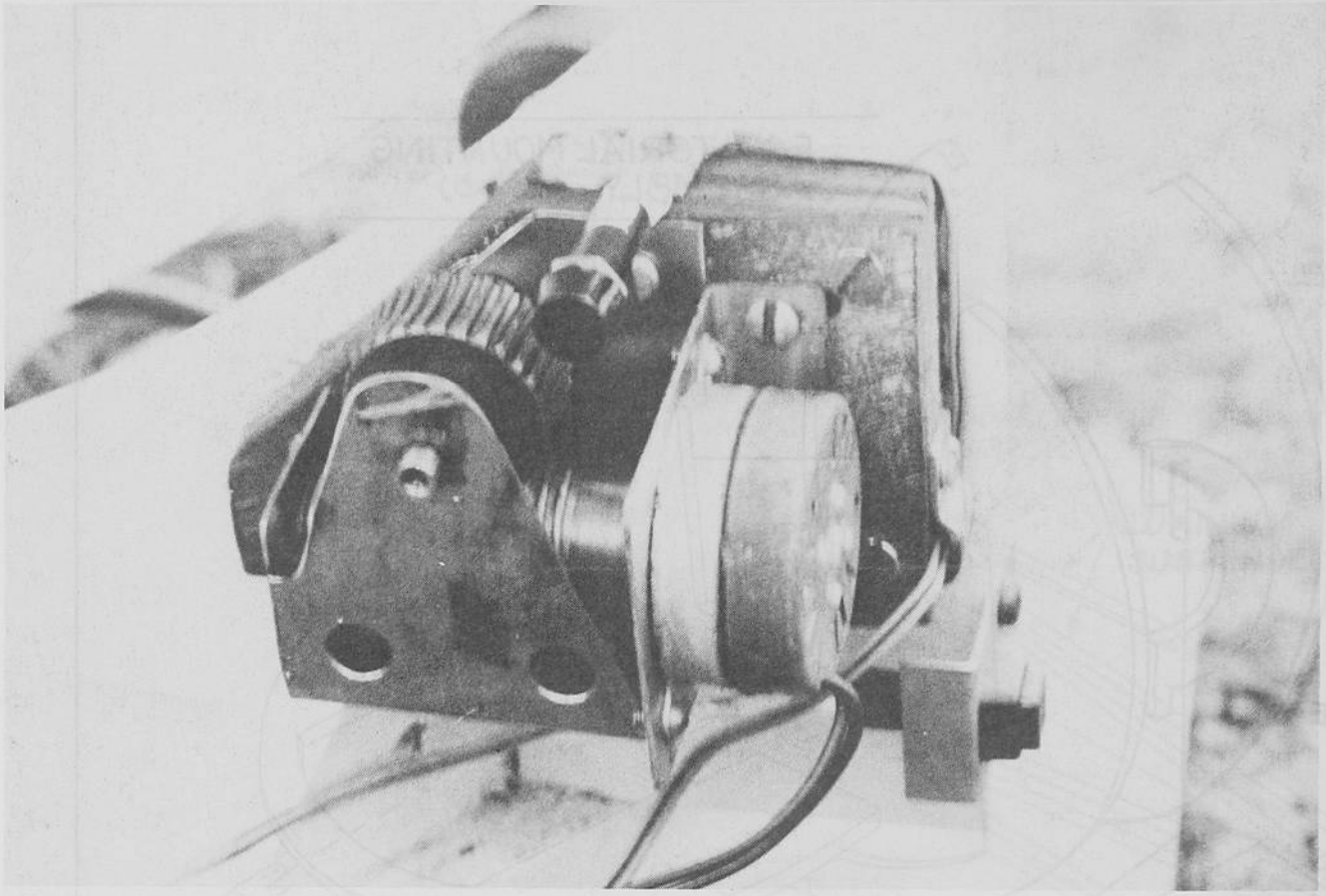

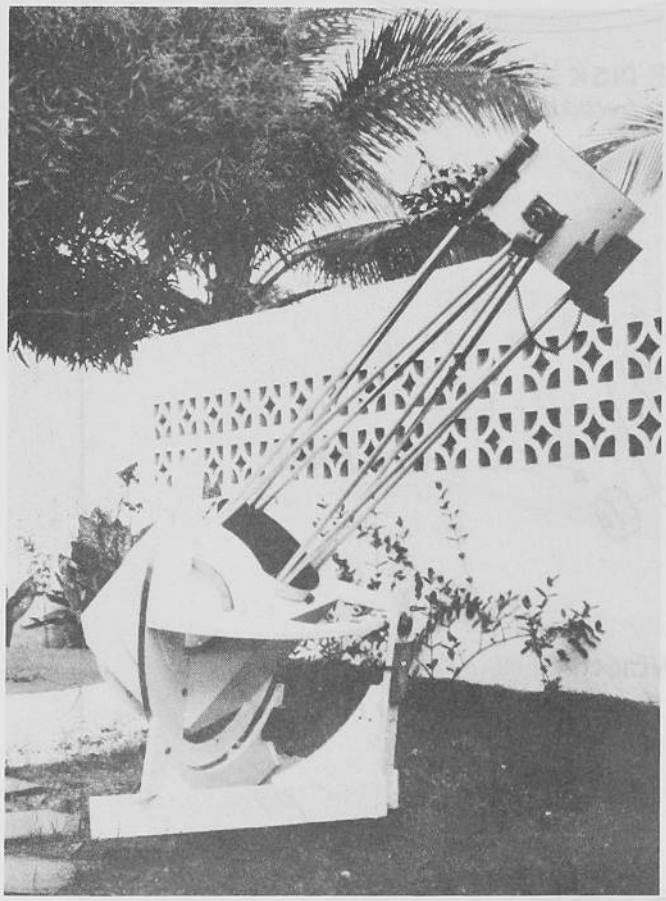

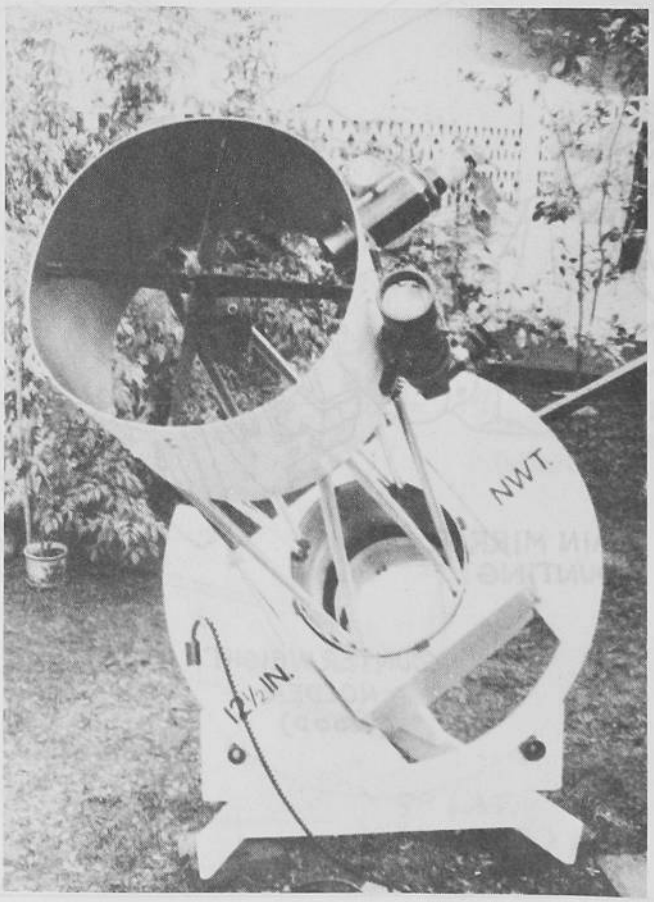
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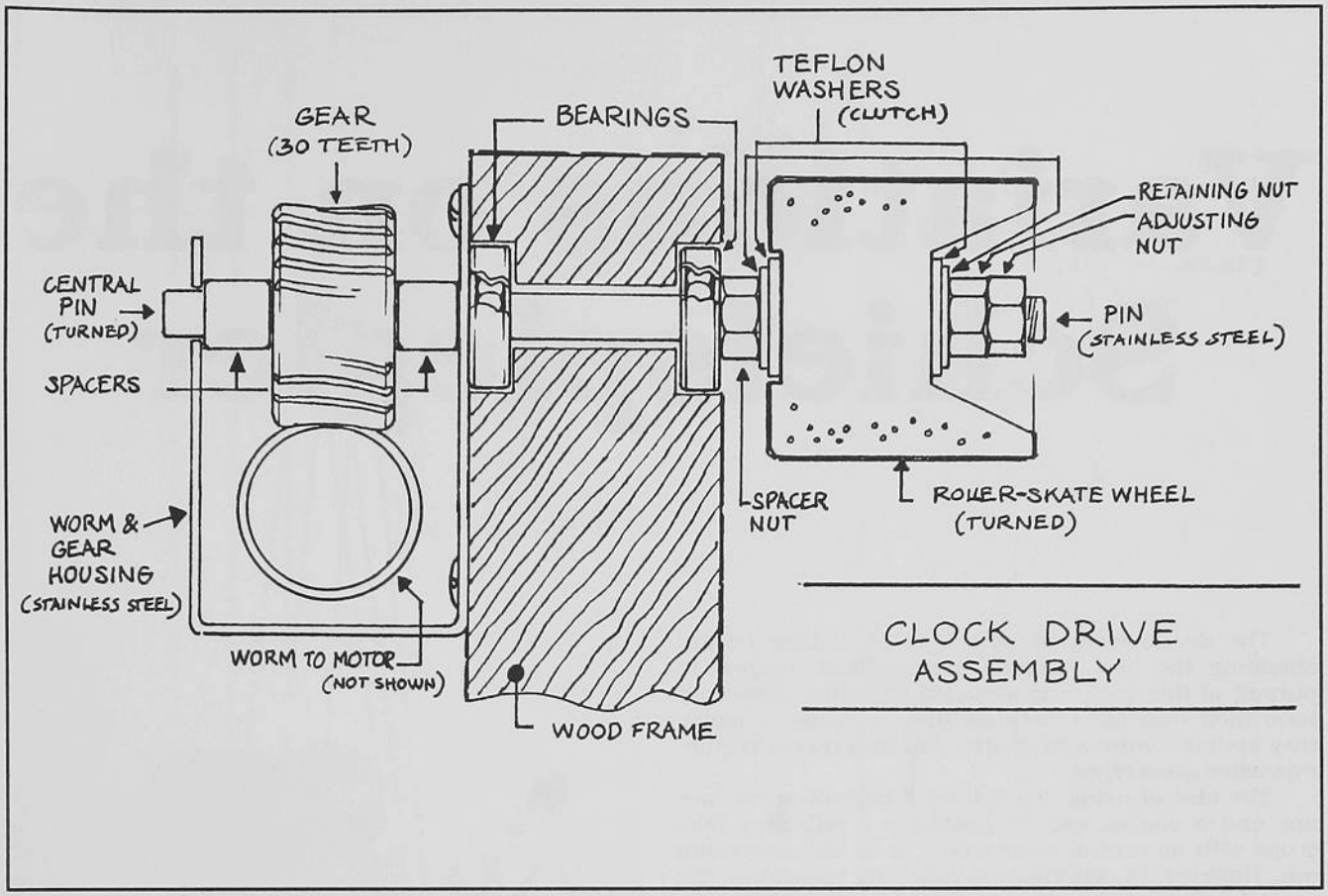



box with its rotating bearings and declination axes. Finally, construct the equatorial mounting with its base which holds the clock drive.

Doing the construction steps in this order minimizes construction errors. You won't wind up with a mounting that's either too big or too small for the optical system.

It took me about six weeks to complete the telescope. The experience leads me to advise the following: In order to get the best performance, don't hurry your work. Make accurate drawings for each step and select only the best high-quality materials for the project.

Note that the declination axes have a Dobsonian design. This makes it easy to remove the tube assembly from the mounting. The systems for rotating the tube allow me to have comfortable viewing at nearly any elevation from the horizon to the zenith. I attached an off-axis counterweight behind the main mirror to compensate for the weight of the finder, focuser, and eyepieces. All moving parts, except the polar disk, bear on pads of Teflon, which results in ultra-smooth motion.

I salvaged the clock drive from an old washing machine control panel. It contained a high torque motor with a speed of one revolution per hour. I machined a plastic roller skate drive wheel to the calculated diameter using the following formula to obtain the correct radius:

R=P/24.

In the formula, P is the diameter of the polar disk and R is the diameter of the roller skate wheel fixed to the drive motor. The formula assumes that the drive rotates one turn in one hour. If you want a sidereal-rate drive, divide by 23.9344 instead of 24.

The drive must be designed and constructed carefully to ensure that the telescope will track a star or planet without drifting out of the field of a high power eyepiece. Two small Teflon washers mounted behind the nuts of the drive wheel allow the drive wheel to slip. That's needed so you can quickly move the telescope to view another part of the sky. I will soon be adding a drive corrector which will allow me to make the tracking corrections needed for astrophotography.

The equatorial mounting can be quickly folded up to carry the telescope to another observatory site with a minimum of take-down and set-up time. This makes it easy to carry in the back of my car. It is a pleasure to use and provides excellent images of stars, planets and deep sky objects. It is easy to transport, set up and use any night, any place and any time.

The instrument turned out to be a precise, smoothly operating, and beautiful looking telescope. It is the center of attention at our star parties. At present, it is the largest-aperture telescope in Panama.

Luis A. Harris
President
Asociacion Panameda
de Aficionados a la Astronia
PULBLITRES, S.A.
P.O. Box 6-3495 El Dorado
Panama, R.P.

*Close up, the clock drive motor unit is simple and solid, readily adaptable to virtually any roller-driven telescope. Below: Profile and front-on views of the 12.5-inch split-ring equatorial look both familiar and strange to temperate-zone observers because of the very low angle of the polar axis. The mounting folds for transport.*

# Variations on the Schiefspiegler

The development of telescopes is a drive toward obtaining the best possible astronomical images. In pursuit of this goal, unobstructed reflecting telescopes have their own place because they are easy to make, they are inherently achromatic, and they do not require expensive glass types.

The idea of using two spherical mirrors, a concave one and a convex one, to configure a reflecting telescope with no central obstruction, is an old and useful one. However, in conventional reflecting telescopes, the central obstruction due to the secondary mirror degrades the image contrast, and the support spider of this mirror introduces cumbersome image artifacts.

In his book about the Schiefspiegler, Anton Kutter tells us how the "oblique telescope" was developed over the last three centuries. Twenty-three years after Gregory's classic paper, and thirteen years after Cassegrain's announcement of his design, Kutter writes that in "Oculis Artificialis," a certain Father Zahn described a Schiefspiegler. The advantage was the unbored primary mirror, but as far as we know, no optician cared enough for this design to build one.

The second father of the Schiefspiegler was the Berlin astronomer Bode. Stimulated by Herschel's front view telescope, he proposed a combination of mirrors in the Berliner astronomische annual (1811) that avoided the need for a hole on the main mirror. Following a publication of the well known German optician Schroder in the second half of last century, around 1830 an English inventor seems to have picked up the idea of the "eccentric mirror telescope". Even at this time, Kutter continues, the Schiefspiegler remained unborn.

In the seventies of last century, the Viennese opticians Forster and Fritsch developed the eccentric Cassegrain and obtained an Austrian patent for it. In the years during and after World War II, Anton Kutter perfected and studied in detail the design that we know as the Schiefspiegler. Not only did Kutter develop a theory for the design, but he gathered and published historical data and a number of important practical details for the construction of such a telescope.

*In a Schiefspiegler, the primary mirror is often mounted in a short tube at the rear; the secondary mirror is at the end of the long tube. The instrument shown is a Kutter Schiefspiegler that belonged to Robert Cox.*

**Variations on the Schiefspiegler.** There are many ways to arrange two spherical mirors, one a concave primary and a other other a convex secondary, to make an unobstructed telescope. However, because of coma and astigmatism, only a few configurations perform well.

The layout of a Schiefspiegler is determined by the mirror separation and by the ratio of the curvatures of the two mirrors. The primary mirror is tilted to place the secondary outside the incoming light beam, and the tilt of the secondary is used to correct or balance aberrations resulting from the tilts.

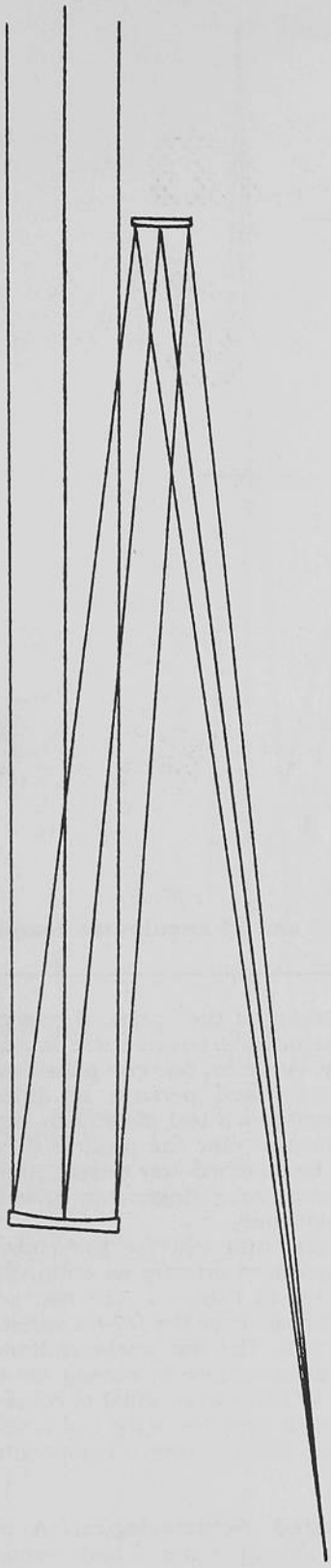


**Figure 1: The Kutter Schiefspiegler**

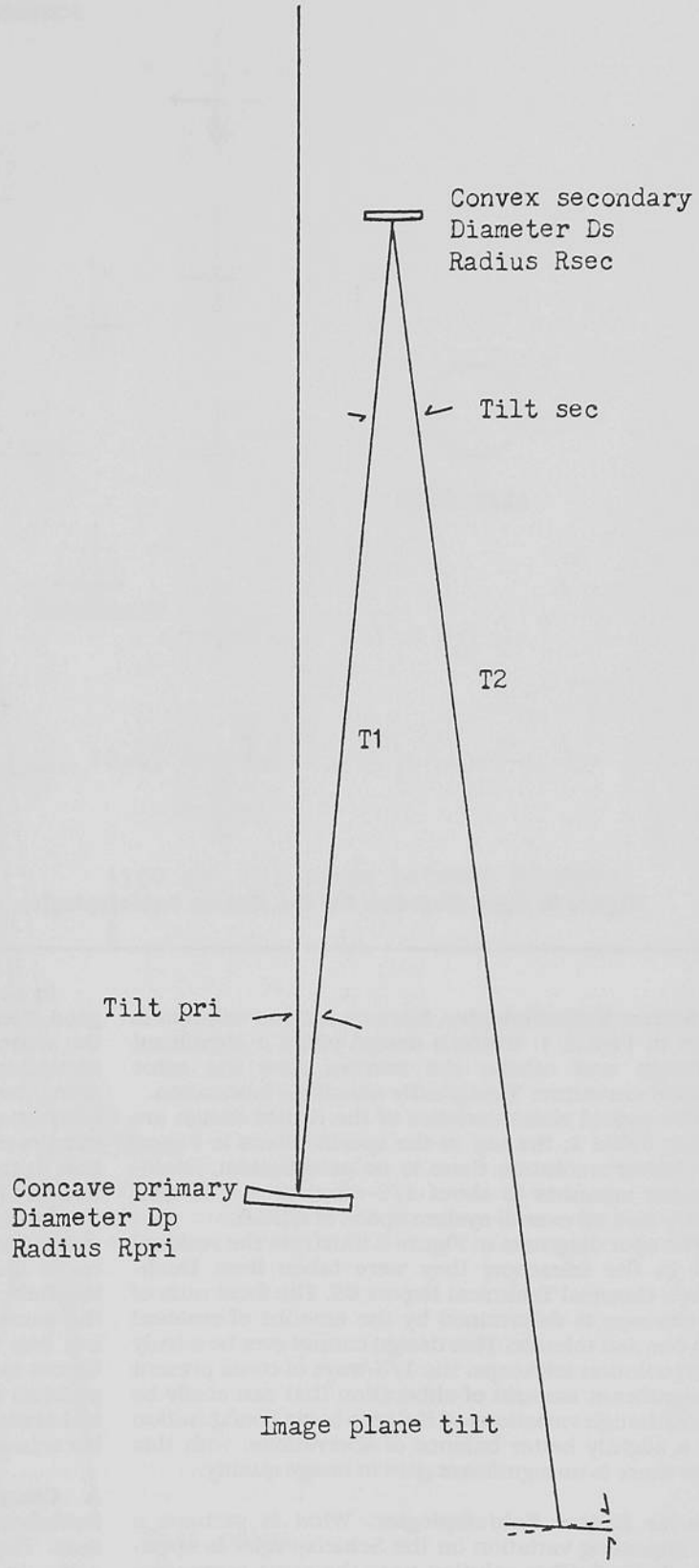



**Figure 2: Nomenclature**

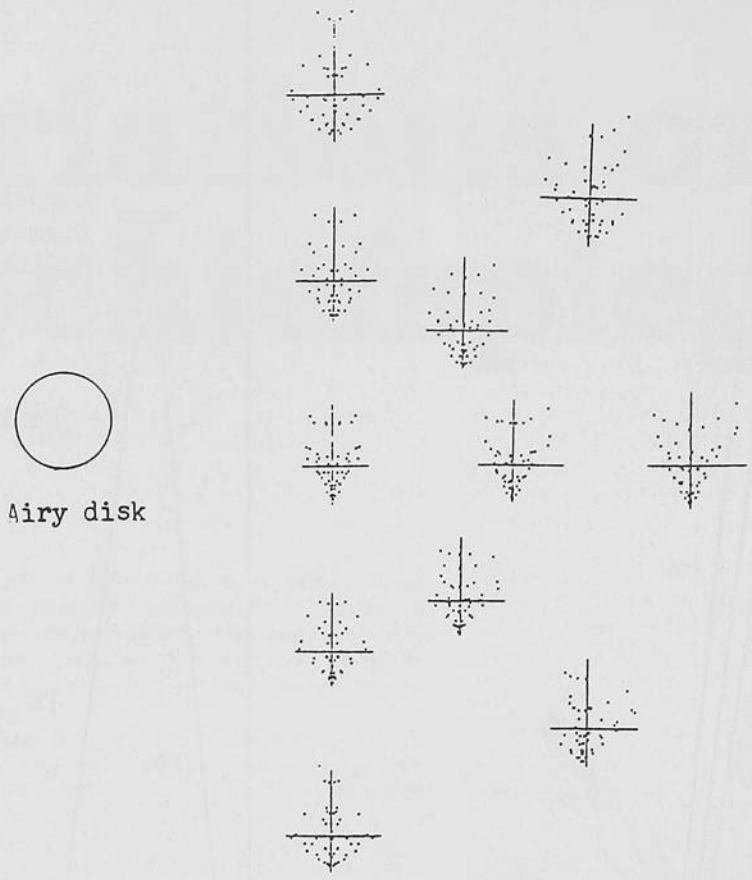



**Figure 3: Spot diagrams for the Kutter Schiefspiegler, at 3.8 and 15 arcminutes semifield**

**The Kutter Schiefspiegler.** Kutter's famous solution is shown in Figure 1. Kutter's design offers a significant advantage over others: the mirrors have the same radius of curvature. This greatly simplifies fabrication.

The optical characteristics of the Kutter design are given in Table 1; the key to the specifications is Figure 2. In Kutter's solution there is no astigmatism. Residual coma amounts to about 1/3-wave for a 4.25-inch primary and an overall system speed of f/26.6.

The spot diagrams in Figure 3 illustrate the residual coma in the telescope; they were taken from Buchroeder's classical Technical Report 68. The focal ratio of the telescope is determined by the amount of residual coma one can tolerate. This design cannot ever be a truly high-resolution telescope; the 1/3-wave of coma present is a significant amount of abberation that can easily be seen. Although variations of Kutter's basic configuration have a slightly better balance of aberrations, with this design there is no significant gain in image quality.

**A Faster Kutter Schiefspiegler.** What is perhaps a more appealing variation on the Schiefspiegler is specified in Table 2. This solution uses the same mirrors as the Kutter system, but has a faster f/24.3 focal ratio for the same amount of residual aberrations. The net gain in focal length is two mirror diameters, and the physical configuration is shorter.

In the making of the optics, if one proceeds with good telescope-making sense, there is no need to test the secondary. However, one can polish the back of the secondary mirror and perform an interference test using the primary as a test plate. This complicates the fabrication because now the radii of curvature of the mirrors must be matched very closely, and some distortion in the interference fringes may arise if the glass is not very homogenous.

An alternate null test for the convex secondary using the aluminized primary as an auxiliary test mirror is illustrated in Figure 4. The test is intended for the Kutter mirrors or for the f/24.3 variation that uses the same mirrors. The test works at finite conjugates, but has the disadvantage of having too long test distances and a 1/15-wave residual of coma (this is not a problem since the purpose of the test is to detect spherical aberration). Nevertheless, it is presented as a possible solution.

**A Compensated Schiefspiegler.** A well-corrected Schiefspiegler should be free of both coma and astigmatism. The simultaneous correction of astigmatism and coma, in an unobstructed telescope with a concave primary and a convex secondary using spherical mirrors, has in the past been considered impossible. However, third-order aberration theory indicates that such a correction is in fact possible.

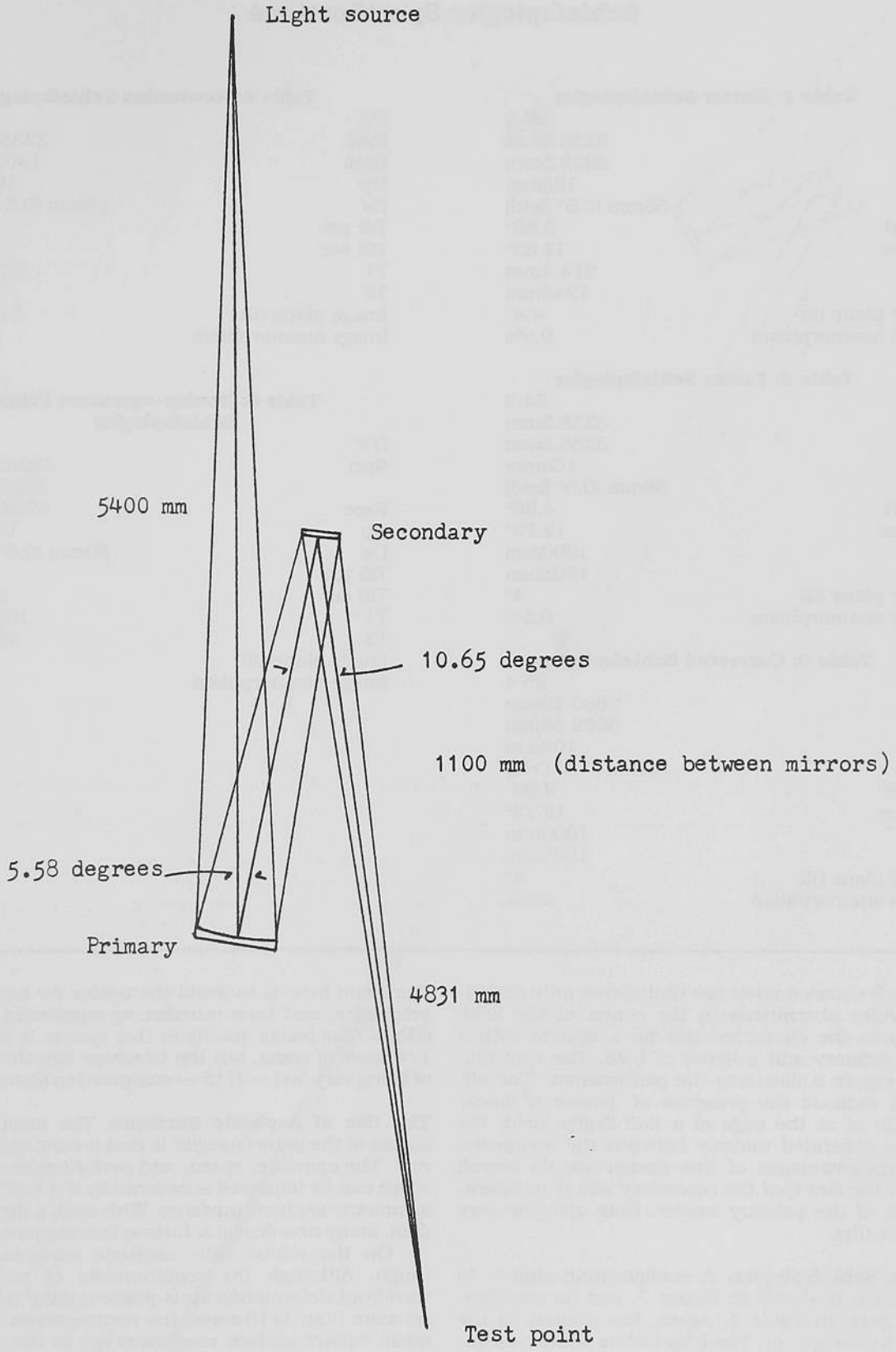



**Figure 4: Null test configuration for Schiefspiegler mirrors**

## Schiefspiegler Specifications

**Table 1: Kutter Schiefspiegler**

| | |
|---|---|
| f/# | 26.6 |
| Rpri | 3238.5mm |
| Rsec | 3238.5mm |
| Dp | 108mm |
| Ds | 56mm (0.5° field) |
| Tilt pri | 5.58° |
| Tilt sec | 12.83° |
| T1 | 914.4mm |
| T2 | 1248mm |
| Image plane tilt | 4.4° |
| Image anamorphism | 0.6% |

**Table 2: Faster Schiefspiegler**

| | |
|---|---|
| f/# | 24.3 |
| Rpri | 3238.5mm |
| Rsec | 3238.5mm |
| Dp | 108mm |
| Ds | 50mm (0.5° field) |
| Tilt pri | 4.86° |
| Tilt sec | 12.73° |
| T1 | 1000mm |
| T2 | 1003mm |
| Image plane tilt | 4° |
| Image anamorphism | 0.5% |

**Table 3: Corrected Schiefspiegler**

| | |
|---|---|
| f/# | 25.4 |
| Rpri | 2880.43mm |
| Rsec | 5069.56mm |
| Dp | 108mm |
| Ds | 50mm (0.5° field) |
| Tilt Pri | 4.86° |
| Tilt sec | 12.73° |
| T1 | 1000mm |
| T2 | 1003mm |
| Image plane tilt | 4° |
| Image anamorphism | 0.5% |

**Table 4: Newtonian Schiefspiegler**

| | |
|---|---|
| f/# | 15 |
| Rpri | 3238.5mm |
| Rsec | 13000mm |
| Dp | 108mm |
| Ds | 18mm (0.5° field) |
| Tilt pri | 2° |
| Tilt sec | 92° |
| T1 | 1550mm |
| T2 | 70mm |
| Image plane tilt | 1 degree |
| Image anamorphism | 1.4% |

**Table 5: Double-curvature Primary Schiefspiegler**

| | |
|---|---|
| f/# | 24 |
| Rpri | 3238.5 and 3229.5mm |
| Rsec | 3238.5mm |
| Dp | 108mm |
| Ds | 50mm (0.5° field) |
| Tilt pri | 4.86° |
| Tilt sec | 20.36° |
| T1 | 1000mm |
| T2 | 997mm |
| Image plane tilt | 6° |
| Image anamorphism | 1.4% |

Figure 5 shows a telescope that shows only negligible high-order aberrations in the center of the field. Table 3 gives the characteristics for a system with a 4.25-inch primary and a speed of f/26. The spot diagrams in Figure 6 illustrate the performance. The off-axis spots indicate the presence of 1-wave of linear astigmatism of at the edge of a half-degree field; the spots were generated midway between the astigmatic foci. The disadvantages of this design are its overall length and the fact that the secondary size is comparable to that of the primary mirror. Note also the very large mirror tilts.

**Newtonian-Schiefspiegler.** A configuration similar to the Newtonian is shown in Figure 7, and its specifications are given in Table 4. Again, the primary is the 4.25-inch Kutter mirror. The long-radius convex secondary obstructs the incoming light beam slightly, but the effects on the image from this obstruction are negligible because it is only 1/10 the primary diameter.

In his article in TM#40, Richard Berry shows how little obstructions that are small affect the Airy pattern. The issue here is to avoid the spider for mounting the secondary, and thus introducing significant diffraction effects. The image quality in this system is limited by a 1/4-wave of coma, but the telescope has the advantage of being very fast — f/15 — compared to Kutter's design.

**The Use of Aspheric Surfaces.** The most appealing aspect of the Schiefspiegler is that it uses spherical mirrors. The aperture, speed, and performance of this telescope can be improved substantially if it has non-axially symmetric aspheric surfaces. With such a degree of freedom, many new design solutions become possible.

On the minus side, aspheric surfaces are often rough. Although the requirements of peak-to-valley wavefront deformation for a prime-quality telescope are no more than 1/10-wave, the requirements for the root mean square surface roughness are in the order of 1/100-wave. Dick Suiter has written an excellent article in TM#28 about this subject.

Unfortunately the fabrication of such aspheric surfaces with the low levels of surface roughness desirable is not feasible for the amateur telescope maker. Proba-

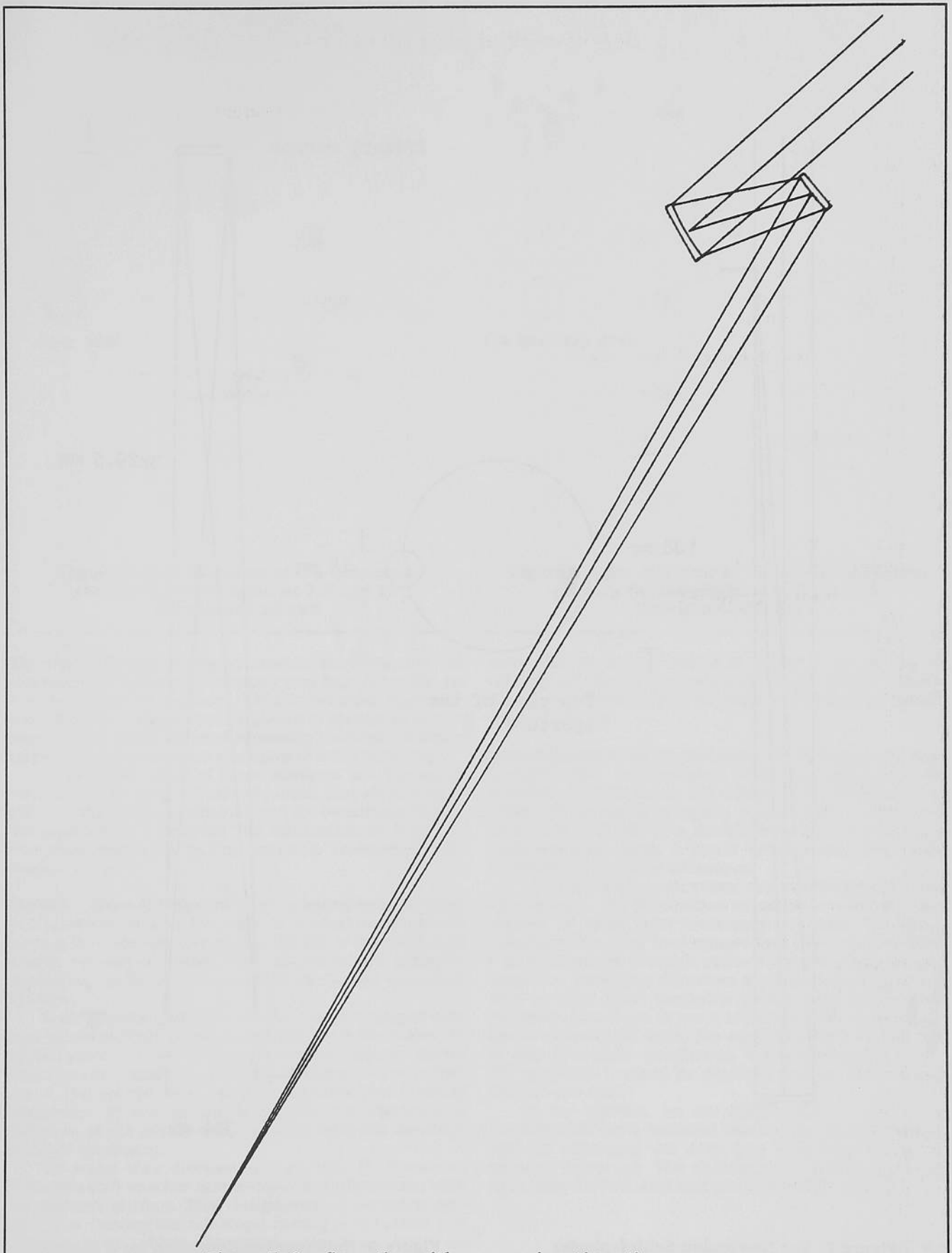
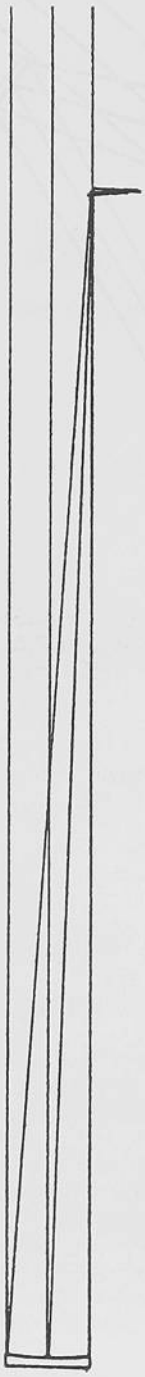
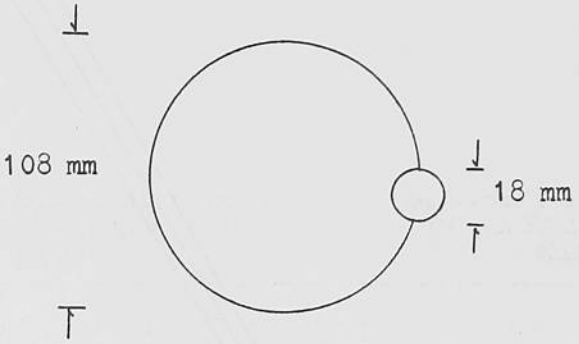


**Figure 5: Configuration with no on-axis astigmatism or coma**





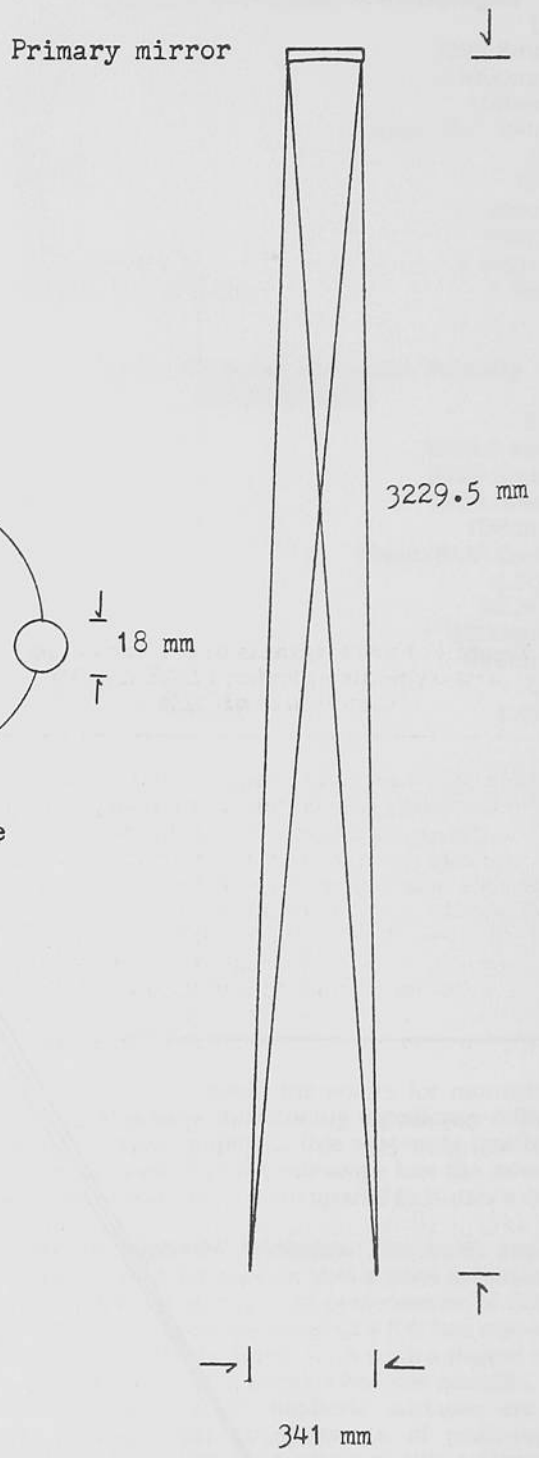




**Figure 7: The Newtonian-Schiefspiegler configuration**

**Figure 9: Null-Test configuration for a double-curvature primary mirror**

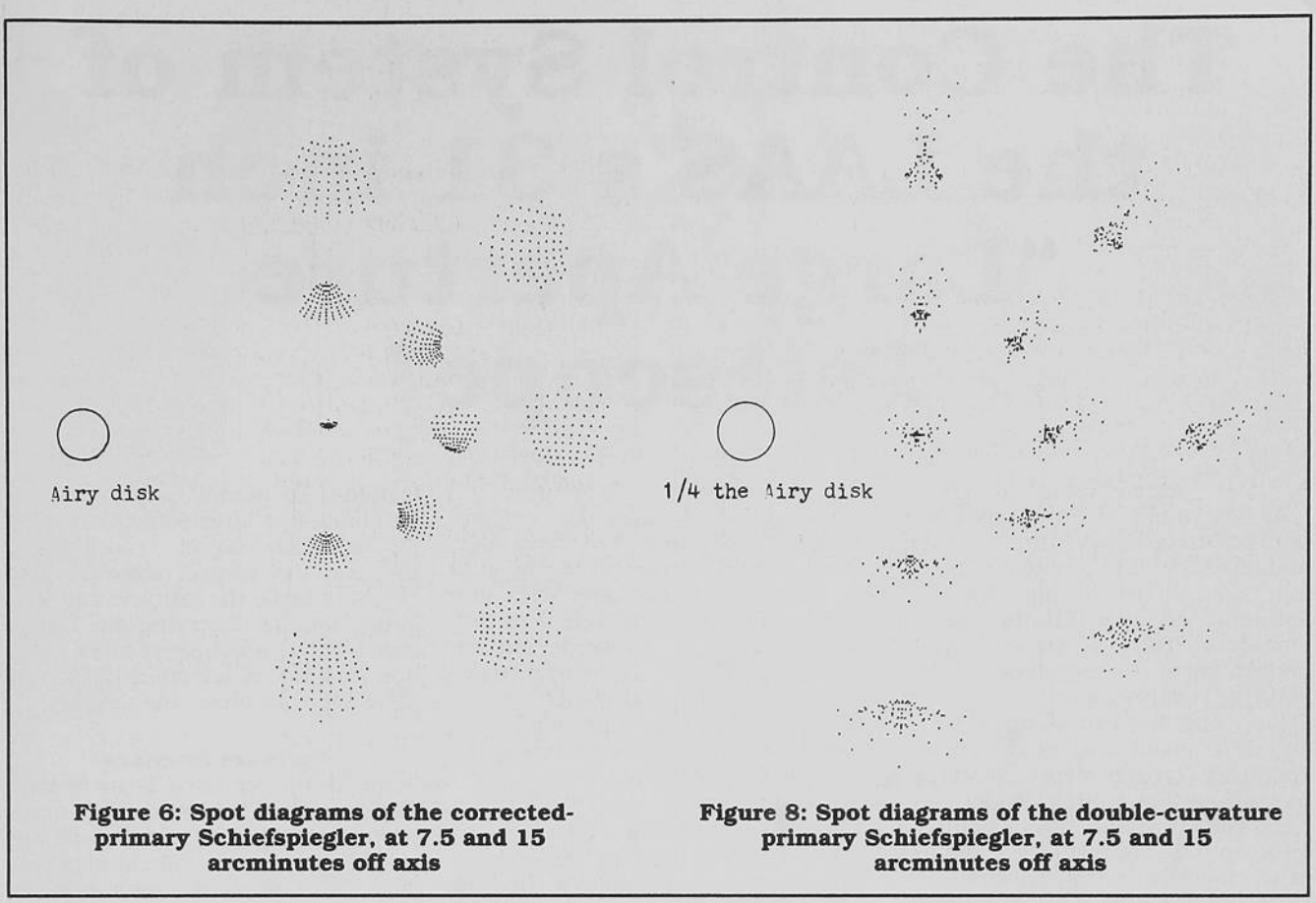



**Figure 6: Spot diagrams of the corrected-primary Schiefspiegler, at 7.5 and 15 arcminutes off axis**

**Figure 8: Spot diagrams of the double-curvature primary Schiefspiegler, at 7.5 and 15 arcminutes off axis**

bly, the only non-axially symmetric surfaces that the amateur can make with certainty and high precision are double curvature surfaces. This is because such surfaces have two perpendicular planes of symmetry which, after all, is a high degree of symmetry. Sections of oblate ellipsoids and toroids are examples of such surfaces.

In practice, all of of these surfaces are equivalent because of the large f/ratio required; just as at long f/ratio a long focus paraboloid and its osculating sphere are equivalent. I describe the fabrication of a double curvature surface in "A Practical Yolo Telescope," S&T, August 1988.

**Doubly Curved-Primary Schiefspieglers.** Doubly curved surfaces can be used to correct astigmatism, leaving the designer free to use the tilt of the secondary mirror to correct coma. Two solutions are possible, depending on the mirror on which the double curvature is made.

Table 5 gives specifications for a Schiefspiegler with a double curvature primary, and Figure 8 illustrates it's performance. Figure 9 shows how the primary mirror could be null tested. In this test, the long-radius meridian of the mirror must coincide with the test plane of symmetry. In use in the telescope, the short-radius meridian of the mirror must coincide with the telescope plane of symmetry.

To make this discussion complete, R. Pressman demonstrated another Schiefspiegler configuration with an aspheric surface. This design was an eccentric section of a Cassegrain telescope having a spherical primary and an oblate-ellipsoidal secondary. Such an eccentric section also has a spherical primary and a secondary being an off-axis section of the oblate ellipsoid. The secondary mirror is obtained by cutting an off-axis section of the relatively small parent mirror. The parent mirror could be made with standard polishing techniques.

**Schiefspieglers In Perspective.** Schiefspieglers demonstrate that unobstructed reflecting telescopes are possible. Variations on the design have different properties. Those using spherical mirrors have limited performance; the use of a double curvature surface in a Schiefspiegler allows a much better correction, larger apertures, and faster telescopes.

Until the last dozen years, our knowledge of optical aberrations, the fabrication of smooth surfaces, and control of stray light necessary to make telescopes capable of the very best images has not been available. I have observed through state-of-the-art amateur telescopes — including refractors and unobstructed reflectors — that have negligible geometrical aberrations. However, I have yet to see a telescope with insignificant levels of scattered light. The scattered light I have seen is due to surface roughness, the tube assembly, and the eyepiece; it could be detected with a carefully performed star test.

In my opinion, we are almost at the end of the development path initiated some three hundred years ago for obtaining the very best telescope images in amateur telescope. The challenge for today's amateurs is to take the last step and actually attain that goal.

Jose M. Sasian
200 Park Place
Naperville, IL 60566

# The Control System of the LAAS's 31-inch "Large Aperture Telescope"

### Introduction

As the trend toward large amateur telescopes continues, more amateurs face the problem of pointing them. A decade ago, however, few solutions lay within the grasp of amateurs. Today's low-cost, high-performance computers make pointing relatively easy.

Easy pointing can be achieved on an alt-az mount when a personal computer controls stepper motors in the two axes of motion. Under computer control, observers can point the telescope by entering the coordinates of the object they wish to observe.

There is already a lot of information available on computer-controlled telescope pointing. Microcomputer Control of Small Telescopes by Mark Trueblood and Russell Genet contains a wealth of information. In this article we describe the details of how the Los Angeles Astronomical Society's 31-inch telescope electronics and computer control system operates.

### History

The LAAS "Large Aperture Telescope" is built around a 31-inch f/4.56 mirror. The mirror was donated to the Society through the efforts of Clyde Tombaugh. In the spring of 1987, members of the LAAS drove the mirror home from New Mexico to Los Angeles with the mirror.

The basic design of the telescope design was done by Steve Kufeld during the trip. The finished instrument is quite close to his original concept — a Dobsonian with a Serrurier truss. We selected the Dobsonian because of the complexities of building an equatorial mount with a 300-pound primary mirror.

Under the leadership of LAAS President Tom Dorff, the telescope mount was constructed out of steel, mostly cut and welded by members of the Society. To complete the construction work took about 18 months.

The finished telescope weighs about 2000 pounds, but it's so delicately balanced that it can be easily moved in either axis with one hand. The telescope was featured on the cover of *Telescope Making #33* and pictured again in *TM#37*. After the mechanical structure was finished, the telescope could be used, but it was cumbersome without the drive system.

### Goals

The LAAS sought to respect the wishes of Clyde Tombaugh. He had asked that the telescope not only be a top-notch amateur instrument, but also be usable by the general public.

We implemented the telescope with three different optical configurations: 1) an f/4.56 Newtonian; 2) an f/12 Nasmith Cassegrain; and 3) an f/20 Nasmith Cassegrain. The Nasmith design allows people to use the telescope without a ladder; this is a definite plus when the general public is involved.

The telescope normally operates under full computer control. With computer control, however, software becomes a design consideration. For example, we put screw jacks at each corner to permit leveling the telescope and prohibit movement once it is situated. This is necessary because the computer software assumes the telescope is level, and any offset from level shows up as a tracking error.

The telescope mount turns on steel wheels that ride on tracks similar to a railroad car. To keep the telescope balanced, we mounted the computer and monitor on one side of the mount and mounted the control electronics in a box on the opposite side.

The computer operator interface needed to be simple enough for members to use without extensive training. To permit easy operation, we obtained a large software catalog of celestial object coordinates. Because the control software also needs to know the latitude and longitude for the observing site but is only used at a couple of sites, location is a menu selection chosen at the start of an observing session.

### Software Interface

The computer used is an 8-MHz IBM PC clone. It has an 8087 math coprocessor chip to handle floating-point trigonometric calculations rapidly. The computer monitor is an amber screen with a brightness control that can easily be turned down. We have found there is little loss of night vision with this arrangement.

As discussed in Chapter 7 of Microcomputer Control of Small Telescopes, the two axes of alt-az mounts are driven independently, and at rates that constantly change speed. The equations that describe the drive rates are:

$$dZ''/dh = 15 \sin A'' \cos \phi$$

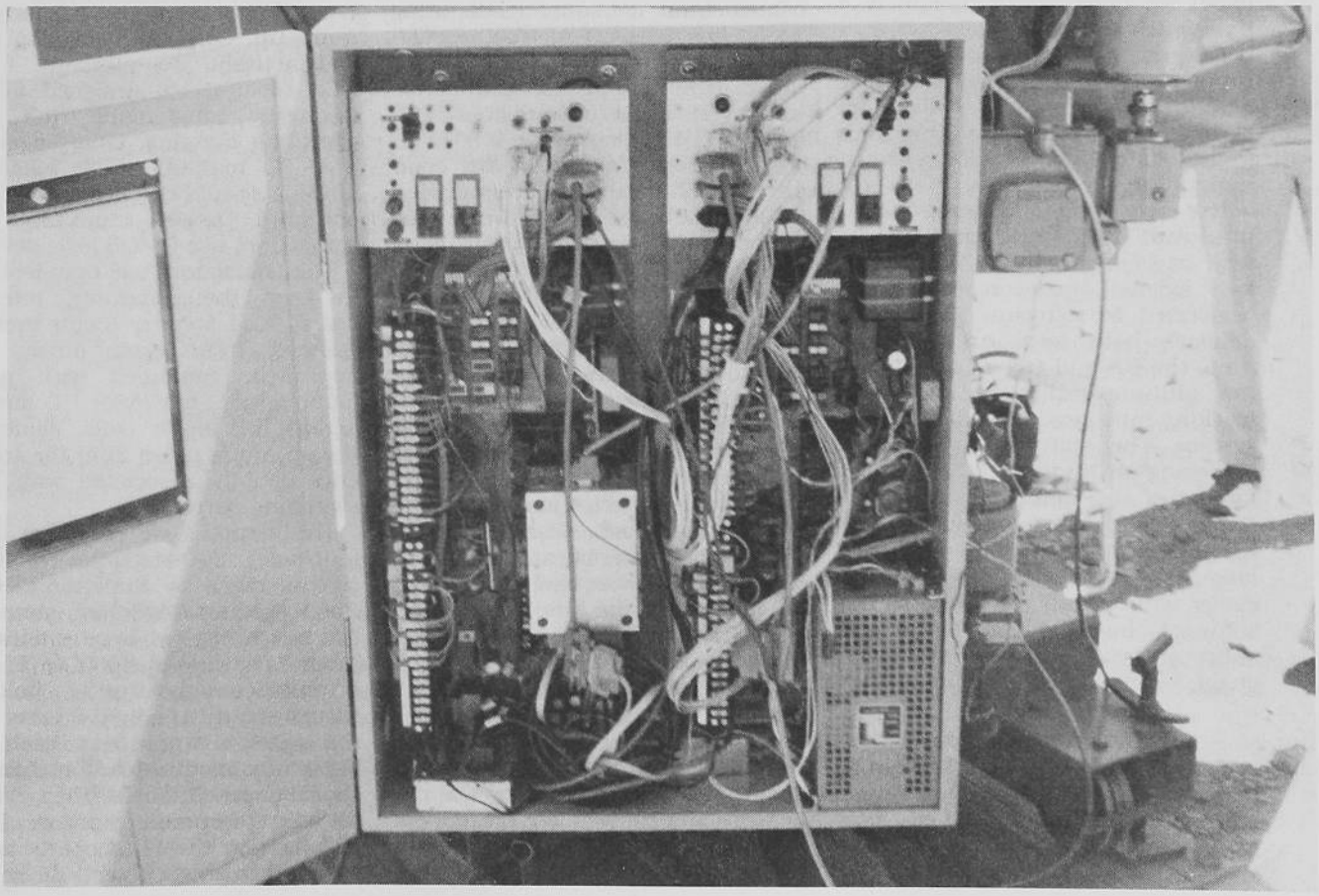
$$dA''/dh = -15 (\sin \phi + \cot Z'' \cos A'' \cos \phi)$$

where:

A = azimuth (measured westward from the south)
h = local hour angle
ø = observer's latitude
Z = zenith distance

and the rates dZ"/dh and dA"/dh are in units of arcseconds per sidereal second. The computer performs these calculations to update the azimuth rate 14 times each second.

*Operating on location, the LAAS telescope employs an open-loop stepper-motor drive system to keep it pointed at the object being observed.*



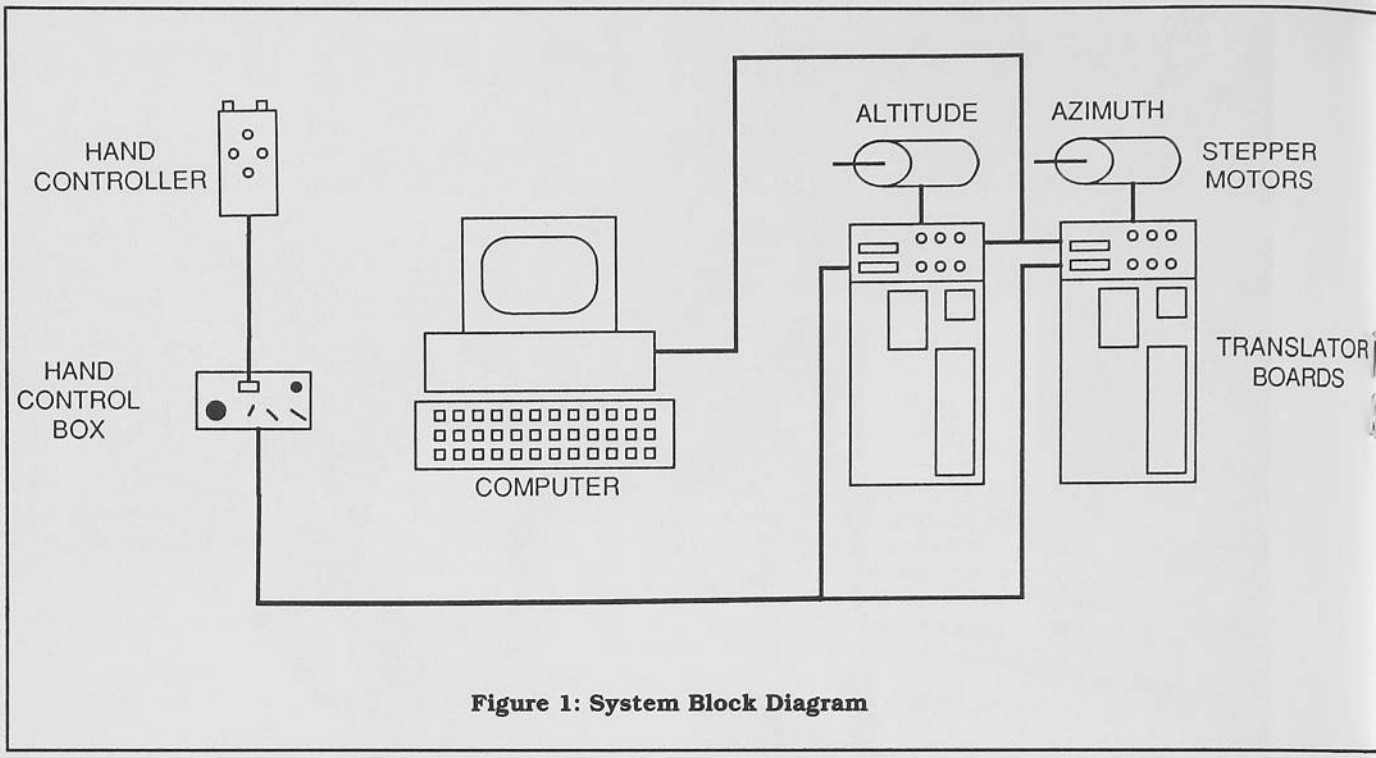



**Figure 1: System Block Diagram**

The altitude rate is updated 4 times each second.

The software also computes the rate for the field rotation. Although this information is not currently used, we nonetheless update it 4 times each second.

The screen display shows the altitutde and azimuth rates, but we update the screen only twice each second to prevent the computer from getting tied down doing screen updating.

The computer maintains local time with a crystal-controlled battery backed-up clock. The necessary sidereal time conversions are performed in software. The screen displays both local and sidereal time, the RA and Dec of the object, the altitude, azimuth, and both tracking rates, and the status of the system. The status can either be "Tracking" or "Stopped."

Most of the software is compiled C, with some of the input/output routines written in 8088 assembly language. The choice of C permits easier writing and modifying of the software, but the frequently-used subroutines are in assembly language for maximum speed.

### Hardware Interface

Figure 1 shows a block diagram of the computer control system. As its output, the program produces four numbers: a direction (CW or CCW) and a drive rate for each axis.

The rate information must be converted from a number to a series of pulses to move the stepper motors. This is done with an add-on board inside the computer. The board comes from Personal Computing Tools, Los Gatos, CA; it's their "D-Max 54" and it sells for $159. The board contains six programmable timers, 48 input/output lines, and its own 1 MHz clock.

Rate information from the computer is fed to a timer programmed to produce a square wave whose period is determined by the drive rate. Two 16-bit timers are chained together to form a 32-bit timer for each axis. With a 1 MHz clock, this allows excellent resolution. It can resolve pulse rates as low as one pulse per 71 minutes!

The software limits the pulse rate to a predetermined threshold (175 pulses per second in our case) to prevent the motors from driving the motors too fast. The computer sends a direction bit along with an enable bit. The square wave from the board and the bits for direction and enable are sent to interfaces that we call "translators."

Figure 2 shows a simplified block diagram of the translators. The translators create the desired sequence of low voltage, high current pulses to drive the stepper motors. Because the steppers require 2.9-volt pulses, we used a 5-volt computer-grade switching power supply and large power transistors to handle the pulses.

Initially, we attempted to devise a method to ramp up the frequency of pulses applied to the motors. However, the present design does not ramp up, and still seems to work satisfactorily. To minimize future field repairs, we designed all the electronic components with large operating margins. Our philosophy was: To maintain high reliability, nothing should be overstressed. For optimum noise immunity, the translators use CMOS logic devices.

The translators use opto-isolators to keep the computer, interface board, and stepper motor grounds isolated from each other. This approach, combined with noise-dampening networks connected across the motor coils, eliminates the spurious noise from the transients usually associated with large switching currents.

The steppers we used are large, four-pole, 200-steps-per-revolution motors made by Superior Electric. Each produces 425 inch-ounces of torque. Multiplied by the telescope mount gearing of 5400 to 1, they produce enough torque to hold the mount steady in a light breeze.

A clutch is connected to each axis. These are modified automobile air-conditioner clutches. They require 12 volts to operate, and are disengaged when the telescope is moved by hand to a new object. When ena-

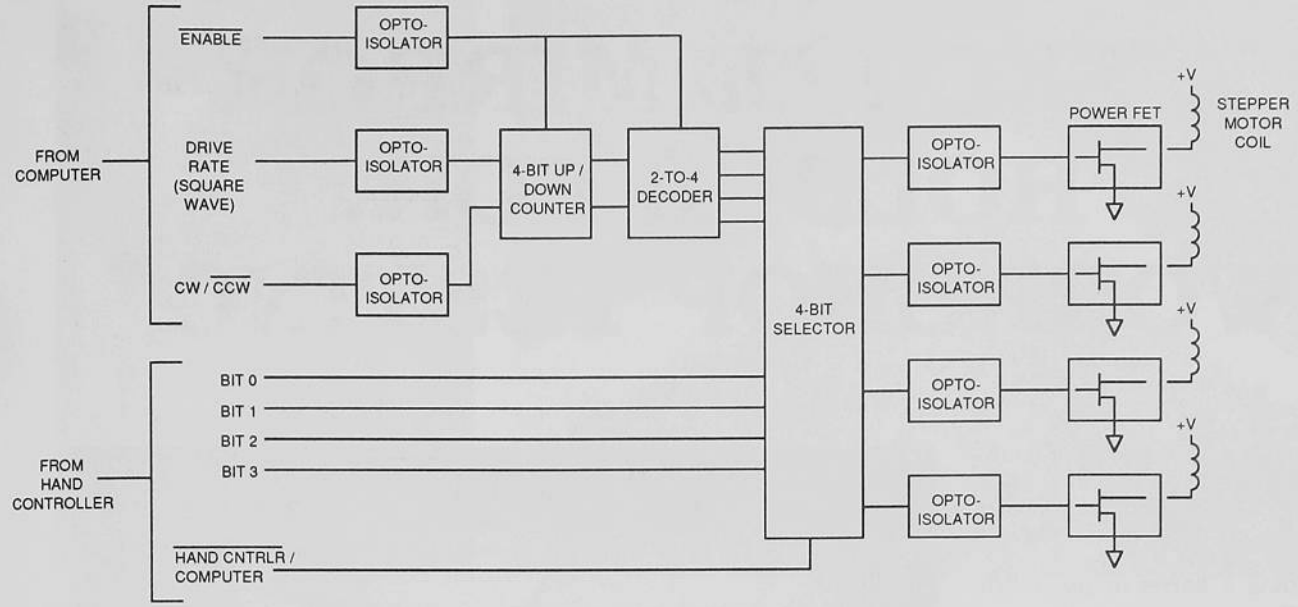



**Figure 2: Block Diagram of the Translator Board**

bled, they effectively prevent free movement of the telescope. The 12,000 foot-pounds of torque produced by the steppers and the gearing drive the clutches through the gearboxes to move the telescope.

Our computer system produces rates of motion; its primary job is to track the telescope. To produce smooth motion requires a large number of steps. At 200 steps per revolution of the stepper motor, and the 5400 to 1 gear ratio, provides 1,080,000 steps to rotate the mount through 360°. This corresponds to 1.2 arcseconds per stepper motor step in either axis.

The price of smooth motion is that the motion is too slow for slewing. For example, to move 30 degrees would take about 8.5 minutes. Without modified gearing, the high resolution we require for smooth motion makes it impractical for the computer to move the telescope a large distance on the sky in a reasonable time.

### Operation

At the start of an observing session, the operators select from a menu or enter the telescope location and then verify the local time. The desired object is entered into the computer by a command such as "M51." The computer looks up, or computes, the RA and Dec of the desired object. The object can be any of the 10,000 objects in the database, or any of the planets. A separate program calculates the planetary coordinates.

Once located in the eyepiece, the user enables the clutches and presses a key to begin tracking. The object under observation remains visible for roughly 10 minutes before errors in the system cause it to drift out of the field of view. With a hand controller, the observer can take control away from the computer to re-center the object, and then go back to computer control. Further work will improve this performance once we better understand the sources of error.

### Future Plans

The LAAS members who devoted long hours to the construction of the Large Aperture Telescope are quite proud of their work. Speaking for those who worked on the electronics and computer controls, we made our share of mistakes. This is probably inevitable when you consider that none of us had ever built a 31-inch telescope control system before!

In retrospect, the best advice we can give to other groups is to first try to make something work, then try to make it work better. Plunge in and get started. We never imagined there was so much involved in the electronics and software. The result shows that perseverance pays off.

With the telescope operational, the Society can keep adding the bells and whistles to make it easier to use. Personally, we don't think it will ever be completely "done," at least for as long as members are willing to invest time and energy in improvements.

In the coming months, we plan to add optical encoders to the drive mechanism to provide position information. These were donated to the LAAS, and mounting locations were designed into the telescope. These will give the observer a readout showing where the telescope is pointed.

One problem mentioned in Microcomputer Control of Small Telescopes is the difficulty in making a drive precise enough to track accurately, and still be fast enough to cross large stretches of sky in a reasonable length of time. Our plan is to continue to slew the telescope by hand, and to use encoders keep track of how far it has gone.

If you are considering a project like this, be prepared to devote a lot of time, effort, and money to the job. However, once you see the telescope in operation, it's all worthwhile. We would be happy to answer technical questions about this project, but to help us handle your letter, please include a self-addressed stamped envelope with your inquiry.

Michael Schettler
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# A SECURE MIRROR HOLDER FOR WORKSHOP TESTING

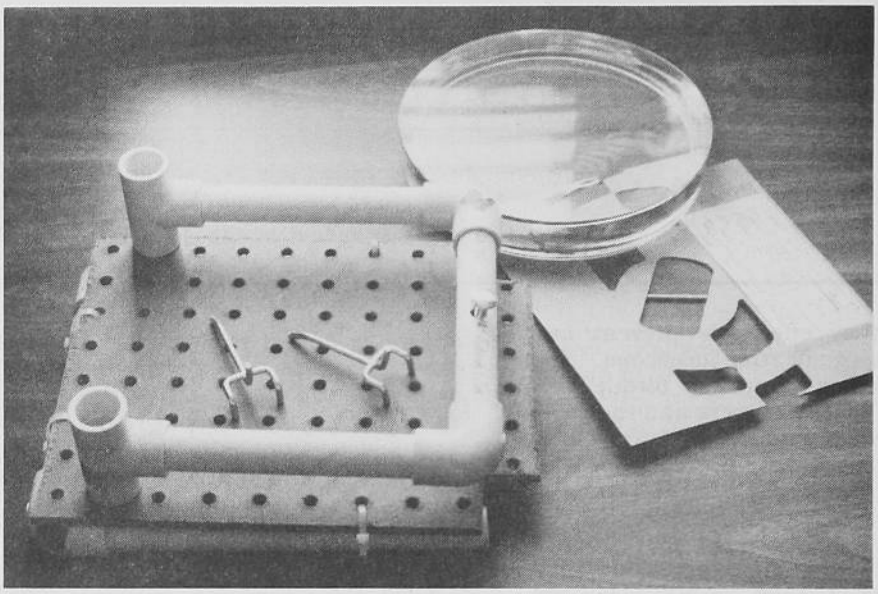
There are a number of sticking points that seem to conspire to stop amateurs from attempting mirror making. In no particular order, an incomplete list is:

1. Finding a barrel or other firm work post
2. Making a tester without machine tools
3. Dealing with the math of the reduction procedures
4. Fussing with all of the little side issues, like making a spherometer or template, getting water near the work location, attempting to get a relatively grit-free environment, and making some sort of holder to set the mirror up on end.

Any one of these is not sufficient to make budding mirror-makers give up, but the aggregate effect can often convince them that it is easier to buy the mirror and concentrate on the mechanical construction.

This is really too bad. I have tried in my writings to bring the stimulating world of optical fabrication to everyone, not always with success. In *TM #22* (*erratum* in *TM #24*), I described a tester that could be constructed with common woodworking tools, and in recent years I have been concerned with developing easy computer methods of reducing the data measured in the zonal Foucault test to a wavefront number. Many of the techniques were described in my *TM #32* article, along with a demystification of previously published material. Glass pushing is not that difficult. Telescope-making writers, including me, have found that it is difficult to discuss verbally what is essentially a visual experience.

A mirror holder was something I kept putting off until I nearly had a bad accident. Actually, that's not quite true. I made a mirror testing stand years ago, but an acquaintance borrowed it and never gave it back. He moved out of state soon after and I never saw it again. The thing looked ratty. He probably thought of it as discardable! Anyway, I never made another one and contented myself to merely prop the mirror up on a chair (if the disk was large) or set it at the bottom of a cardboard box, which I then tilted until it was about horizontal.



*For a few dollars' worth of plastic pipe and pegboard, you can build a solid (and safe!) holder for testing telescope mirrors.*

In other words, I was risking disaster.

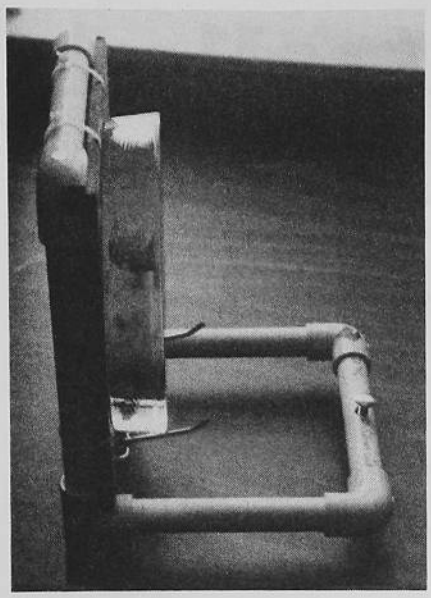
The accident happened when I was testing a finished 8-inch f/6 a couple of years ago. I was sitting about 10 feet away, behind the tester tripod, and trying to get the light source aligned on-axis. The polishing barrel was serving as a table to hold the mirror. I had the mirror propped vertically in a shallow bowl that cupped the bottom. I nearly had it aligned when I noticed the slit seemed to be drifting down in the field of view. I realized to my horror that what I was witnessing was the beginning of a mirror falling flat on its face.

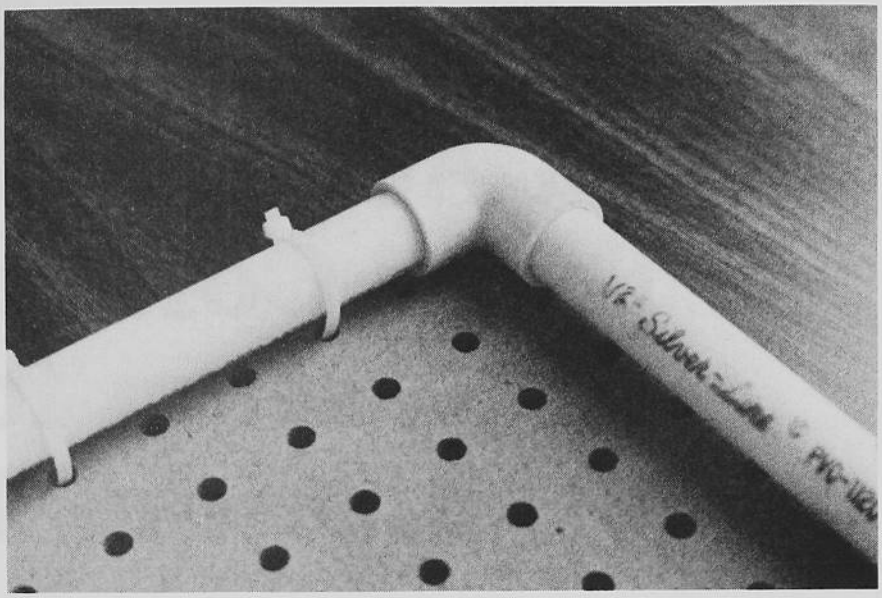
I flung the tester to the side and covered the intervening distance in an instant. Thrusting my hand forward, I caught the mirror just before it touched the clips that held the lower disk during polishing.

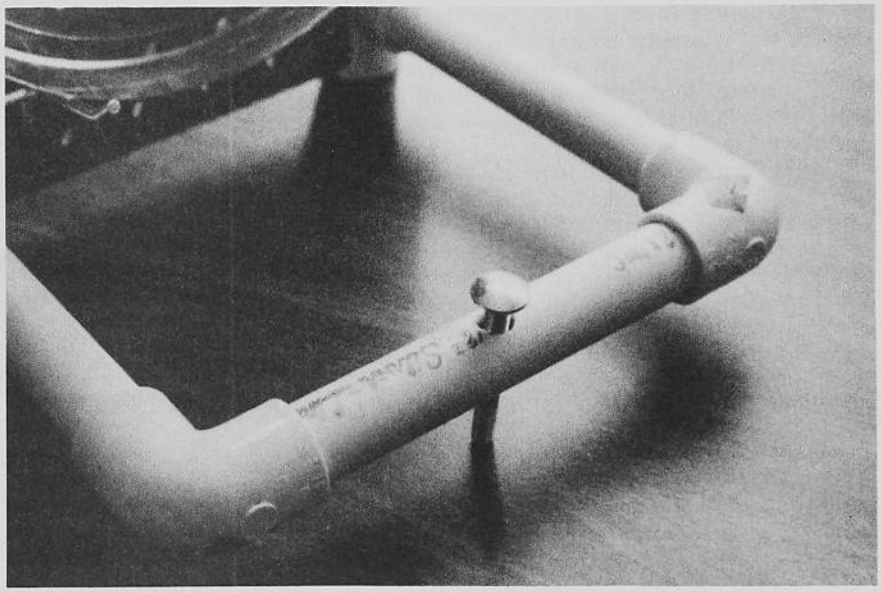
I looked back at the ruination of my tester. A couple hours of work would make it as good as new, but I shuddered to think of the tragedy that nearly befell me. The mirror that would never happen again.

To ensure this I came up with the pegboard-and-PVC design depicted in the photos. I'm not going to discuss design features in detail because most of them are obvious. The desirable characteristics are:

1. It is dirt cheap. Depending on the contents of your junk box and whether you have a scrap of pegboard on hand, you could duplicate







*Closeup pictures show that construction is both simple and quick. Tie-wraps pop through holes in the pegboard and hold the pegboard to the pipe frame. A carriage bolt threaded into a tee-nut provides fine control in elevation, and quick-setting glue bonds the tee-nut into place in the frame. The clips holding the mirror tip up, keeping the mirror secure.*

it for about $2 to $5.

2. It isn't oriented to one mirror size. Many disks can be tested with only minor modifications, such as moving the resting clips closer together for smaller mirrors.

3. Since the clips have an upward tilt, the mirror rests against the pegboard. Often, a topside retainer clip is not even required (these photos were taken with a mirror that didn't need one). If you want added security, it is easy to put a screw through one of the many holes near the top of the disk and loosely hold a wide fender washer on the top front face of the mirror.

4. It scales. By using bigger PVC plumbing and more nylon ties, you can make a big holder to support quite a large mirror. The limiting factor is the structural strength of the pegboard itself. You don't want to support so much weight that it rips the clips out of the holes. I have personally carried up to 12 inch mirrors on a pegboard. I think it would work for large thin mirrors, using some sort of sling and hanging the mirror rather than supporting it from the underside. For big mirrors the top clip once again becomes necessary.

5. It requires only one threaded hole. Visible in the photos is an elevation screw on the front side. I drilled this hole as a 1/4-20 clearance hole on the top, and then tapped a smaller hole out to 1/4-20 on the bottom. The tap is NOT necessary. A much easier way of proceeding, in retrospect, is to drill a bigger hole and just glue a T-nut (flange side down) into place. Use a carriage screw for this adjustment because they're threaded all along their length.

6. Angle adjustment is easy. The T-shaped PVC fittings (below the mirror) give the holder the analog of heels. You can use the screw to adjust the mirror axis to angles on either side of dead level.

7. It stores flat. I left two of the fittings non-cemented so I could take it apart and carry it in my tester box. If you are testing a really heavy mirror, you may want to completely cement it, though.

8. Tie-wraps are forgiving. You don't need to measure accurately to drill the holes for securing the pegboard to the PVC backframe. Close is good enough.

9. It is FAST! I made this in (I swear!) an hour. It took much longer to go to the store and pick up some PVC cement than it took to tack this thing together.

The final advantage is the most important one. It is rock solid. I know it doesn't look too substantial from the photographs, but this holder is very stable. Finally, I have a secure platform to do my testing.

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Panama City, FL 32405-3242

# Build A PC-Controlled Data Acquisition and Error Correction System for Synchronous Drives

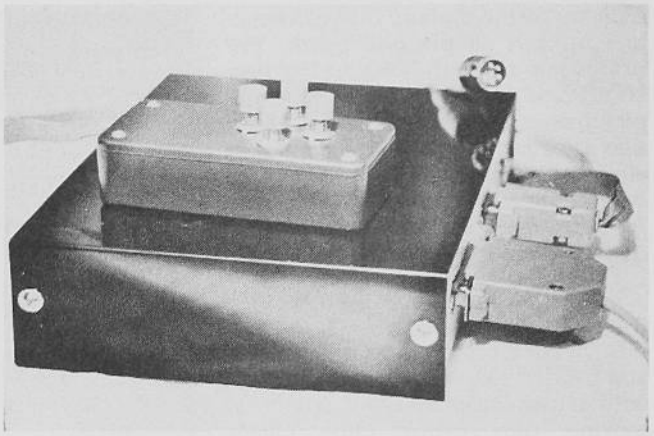
This article is written to provide enough information for the telescope maker with a background in electronics to build a working periodic-error correction (PEC) system. It describes the operation, theory, use, and design limitations of a system that we have built and tested.

After building this system, we performed many hours of testing both on the bench and in the field. The schematics have been checked against the hardware to ensure that there are no errors. All of the electronic circuits have been constructed and tested.

Although the variety of telescopes and drive systems precludes making any guarantee that the system will work perfectly under all conditions, the control program makes changing critical variables easy. We are confident that the telescope maker who sets out to build this system will succeed.

To give a little background, I became curious about the command signals a prototype CCD auto-guiding system operating with my Meade LX3 telescope generated as it overcame alignment and drive errors. To monitor the command signals, I decided to add a serial-linked data acquistion system and link it to my personal computer to acquire and store this information.

However, before I completed the circuit I saw the first ads for commercial PEC drive systems. Not to be outdone, I added serial control of RA and DEC motions to my system. The system can acquire data on drive errors and correct them as well as declination drift.



*The enclosure for the electronics and hand-control is compact and easily added to an existing telescope. The design described has been thoroughly tested, and can be built by any TM with electronics experience.*

### Theory of Operation

Acquisition of the RA and DEC data is needed for evaluation of the scope alignment errors and the gear errors. This requires monitoring the guide commands for one rotation of the worm gear, or about eight minutes. At this point the data may be saved for evaluation or used for drift correction.

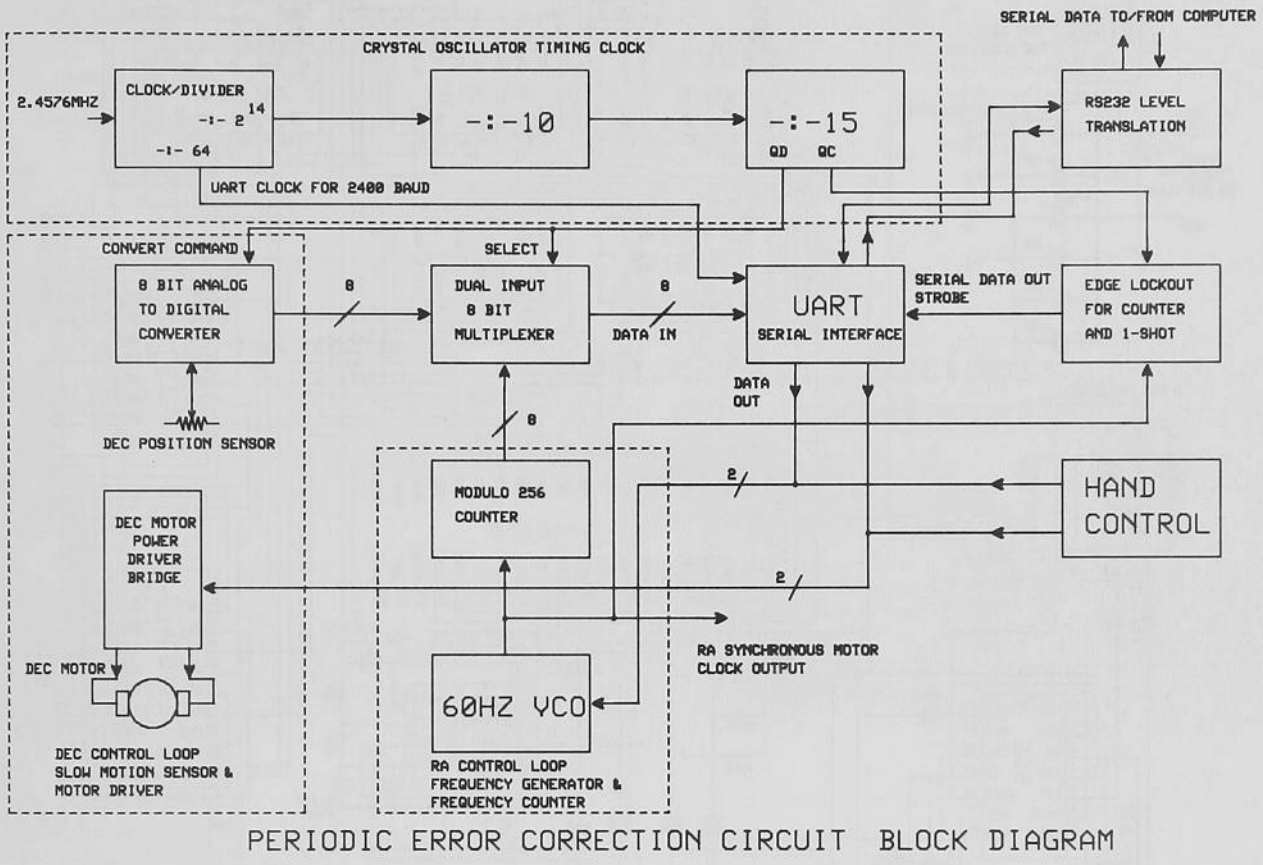
The data acquisition system is based on two fundamental measurements: clock pulses sent to the RA motor and the position of the DEC slow-motion control knob. The RA position is derived from the continuous sum (integral) of the clock pulses to the synchronous motor. The DEC deviation is measured from the position of the DEC fine-motion knob. The control knob is coupled to a potentiometer that senses rotation.

Figure 1 gives a functional block diagram of the complete system. Operation of the system will be broken into an explanation of the data acquisition circuitry and the control circuitry. Figure 2 gives the circuit schematic, and it is broken into two sheets; one contains the electronics and the second contains the hand controller and the computer cable connections.

To track the RA clock pulses, the system uses an eight-bit modulo 256 integral counter. The RA pulse count is sent to the PC (Personal Computer) once a second via the serial interface (UART chip). Edge lockout of the RA clock is required to avoid transmitting corrupted data. Software detects the counter overflow and adjusts the count to the true integral value.

The electrical span of the DEC potentiometer voltage goes to an eight-bit ADC (Analog to Digital Converter) that converts it to one of 256 values. This data is also sent once a second to the PC by the UART.

Time-keeping operations are derived from a crystal-controlled oscillator. A data multiplexer is used to alternate between the RA counter and the DEC ADC eight-bit data. The total elapsed time is kept in software by




PERIODIC ERROR CORRECTION CIRCUIT BLOCK DIAGRAM

**Figure 1**

counting the data sets received.

For error correction, both the computer and the operator must have access to the RA and DEC slow-motion controls. Fortunately, the UART chip is capable of receiving serial data and converting it to control bits. Four of the bits were 'OR' wired to a hand-controlled pad. Either the computer or the operator can simultaneously command the RA speed and the DEC slow motion. The RA speed is generated by a voltage-controlled oscillator (555 timer) and an H-bridge output driver was constructed from a dual 555 timer for the DEC slow-motion motor drive.

Since the serial data rate is fixed by the crystal oscillator, the serial interface has a built-in capability of generating precision timing commands by receiving strings of control characters.

The use of the serial data interface for timing applications allows two methods of control. The first is PPM (Pulse Position Modulation). A fixed pulse width control signal of N-characters is sent whenever the positional error exceeds the displacement that a pulse command will cause. The second method is PWM (Pulse Width Modulation). Here, a command pulse proportional to the error is sent at fixed intervals. In our system, the command signals are sent by software at the acquisition interval of one second. Thus, PPM commands are sent at intervals which are multiples of one second and PWM commands are sent every second.

Drift and PEC correction is based on the PPM method. The program calculates a PPM command control sequence which is derived from the acquired drift data and system self-calibration data. These commands are sent to the slow-motion controls. Normal operation of the slow-motion control is not impaired and the improvements from this type of system significantly reduce the operator corrections.

A closed-loop control method makes it possible to frequency-lock the RA clock to a lunar, solar, or a sidereal rate. The algorithm employed for frequency-locking compares the integral RA clock count to the expected true count. The RA correction command, which is proportional to the count error, drives the RA rate back to the ideal count. With this method, the RA correction pad is not usable since the system will attempt to drive

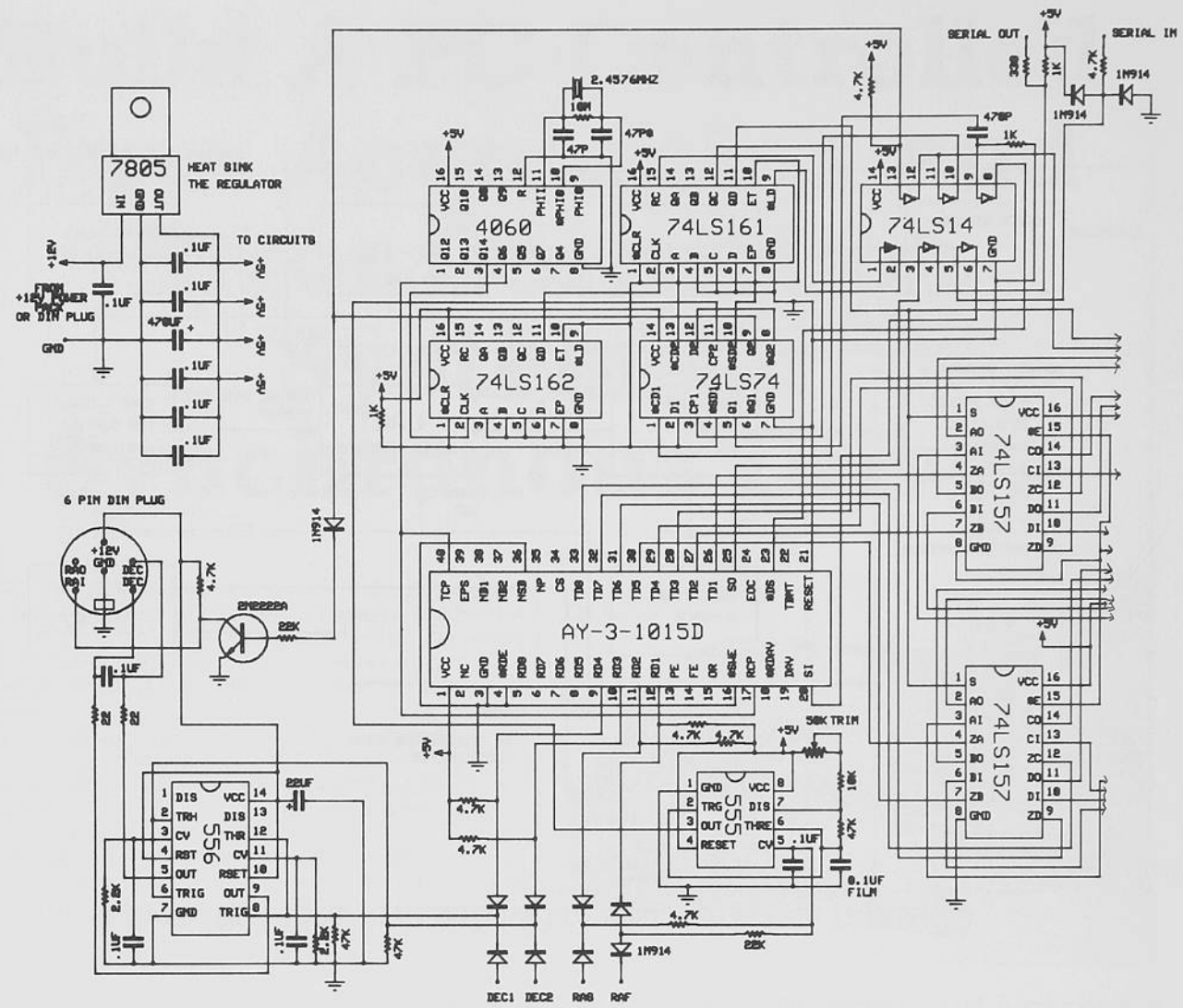



**Figure 2**

the RA frequency back to the ideal rate.

### Construction Hints

We recommend wire-wrapping for construction of the electronics card. Power and ground to the digital chips should be distributed through a buss. I use a 1/2-inch-wide strip of double-sided copper-clad board for the buss. The power-supply bypass capacitors are soldered directly to the strip. A small, separate analog buss should be used for the ADC chip and the power to the potentiometer. The connecting wires from the analog buss should tie directly to the 470uF bypass capacitor on the digital buss. The 10uF tantalum capacitor is soldered across the analog buss.

The potentiometer that senses the rotation of the DEC slow-motion knob must be capable of rotating 360 degrees without running into a stop. Some precision potentiometers of this type are available, but they may be expensive or difficult to locate. A simple modification to a standard linear-taper carbon-element potentiometer provides 360-degree rotation. Remove the back plate by folding back the four metal tabs that hold it. Cut the plastic stop as shown in Figure 3. To prevent the wiper from catching, bridge the gap between the end terminations with a filled epoxy such as JB Weld.

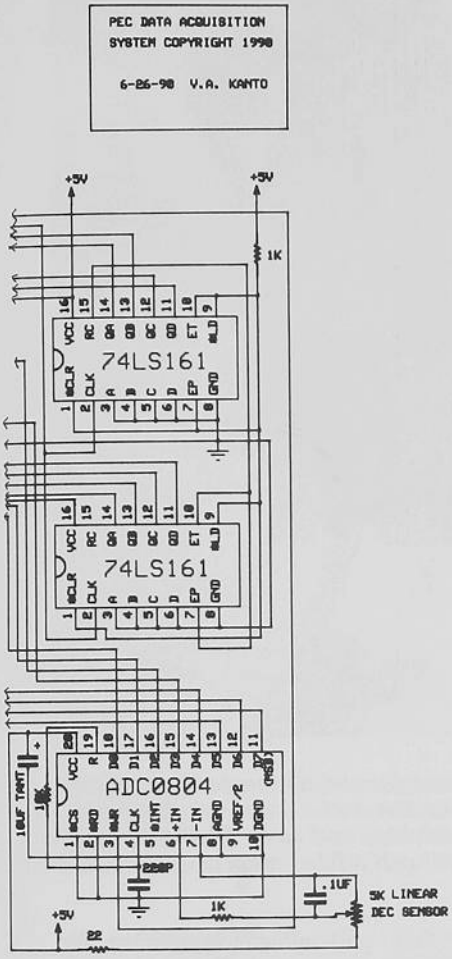
We coupled the potentiometer and the DEC knob with molded plastic hobby racing gears. We bored out an 85-tooth gear and cemented it to the DEC knob. To improve adhesion, the aluminum knob and the gear surfaces were scrubbed with Bon Ami cleanser, rinsed, and dried just prior to the application of the filled epoxy adhesive.

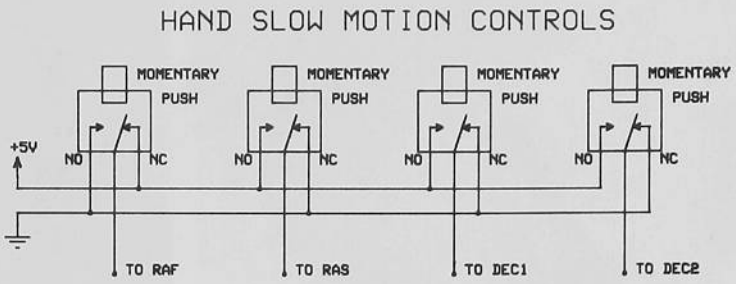
The electrical travel of the potentiometer is about 210 degrees; thus one full turn of the slow-motion knob is about 600 arcseconds. Thus, with a gear having 81 teeth attached to the potentiometer, we have an ADC resolution of:

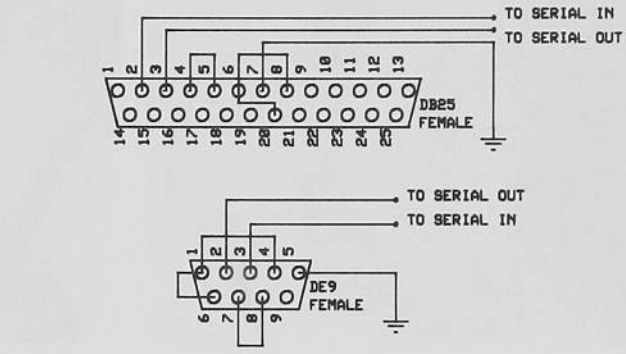
(210°/360°)*(81T/85T)*(600"/256)=1.30 arcseconds.

Full scale is 334 arcseconds. We drilled an aluminum knob through and tapped two holes to mount the gear to the potentiometer. The potentiometer was attached to the fork arm with a spring-loaded bracket. Figure 4 shows the details pertaining to the gear attachments.

The wiring to the potentiometer must be shielded to




prevent signal noise. Miniature shielded cable with a single-stranded center conductor was used due to its flexibility. Two cables are required. The shields are connected directly to the ADC analog ground, on pin 8. The two center conductors are used for the +5V feed and the wiper signal return.

### Software Installation and Operation

The control program was written in Microsoft QuickBasic 3.0. It is intended to run on an IBM PC or compatible with a CGA display adapter. We tested the software on a Zenith SuperSport running at 4.77MHz. After entering the source code, compile it with the following switches:

qb pecv2 /c:1024 /e /o /q /v /w /x

Link the object code with the BCOM30.LIB and the GWCOM.OBJ files:

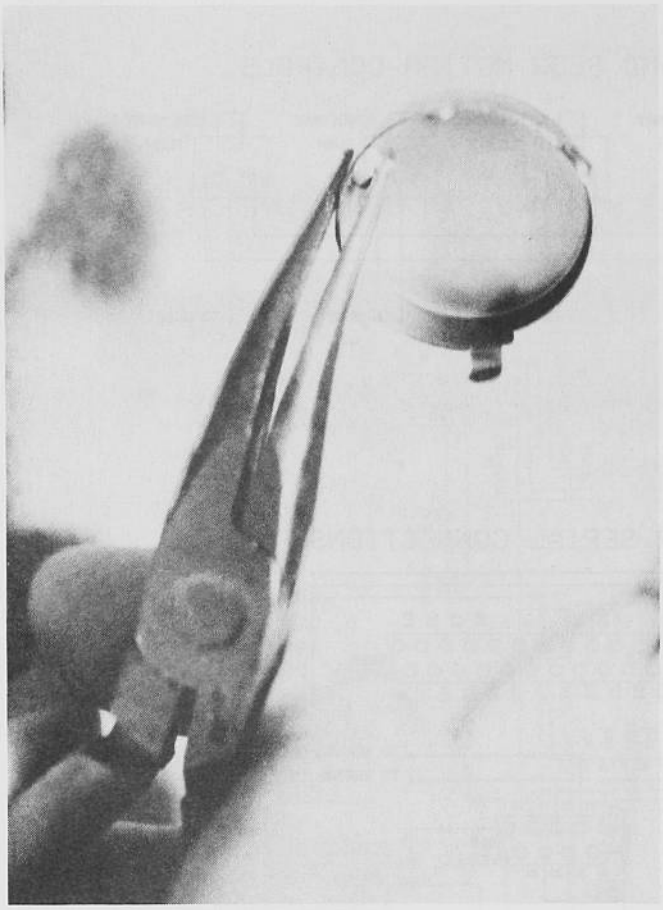
link pecv2+gwcom,pecv2,,bcom30

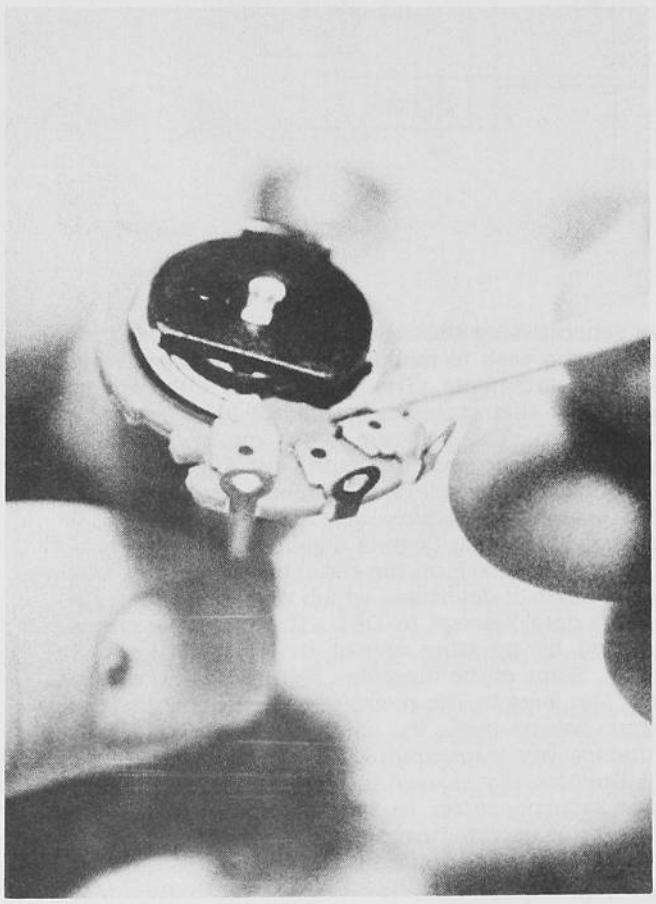
Note that you should check the library names when using other versions of QuickBasic.

The software will not function without the data acquisition system because it relies on an interrupt that is generated by the reception of serial data. Programmers who wish to modify the software should not use INPUT statements. The serial data interrupt is locked out by this statement until the user enters a carriage return. The program relies on key-trapping and key-checking to prevent locking out the interrupts. Thus, all functions are invoked with one key stroke.

The program functions are accessed through a menu page. The menu page is displayed after the system synchronizes itself on the serial data. Synchronization is required to determine which data belongs to RA and which data belongs to DEC. The menu functions are invoked by pressing one of the number keys, 1 through 4. Some of the functions require additional key strokes. The keys in the menu are marked by braces; (C)ontinue means press the capital C key to continue. Two function key traps are used for special operations. The F1 function key is used to break out of any operation and return control to the menu page. The F10 function key is used to rezero the RA drift plot.

Prior to making a long, guided exposure, the system should be calibrated. The RA normal frequency is



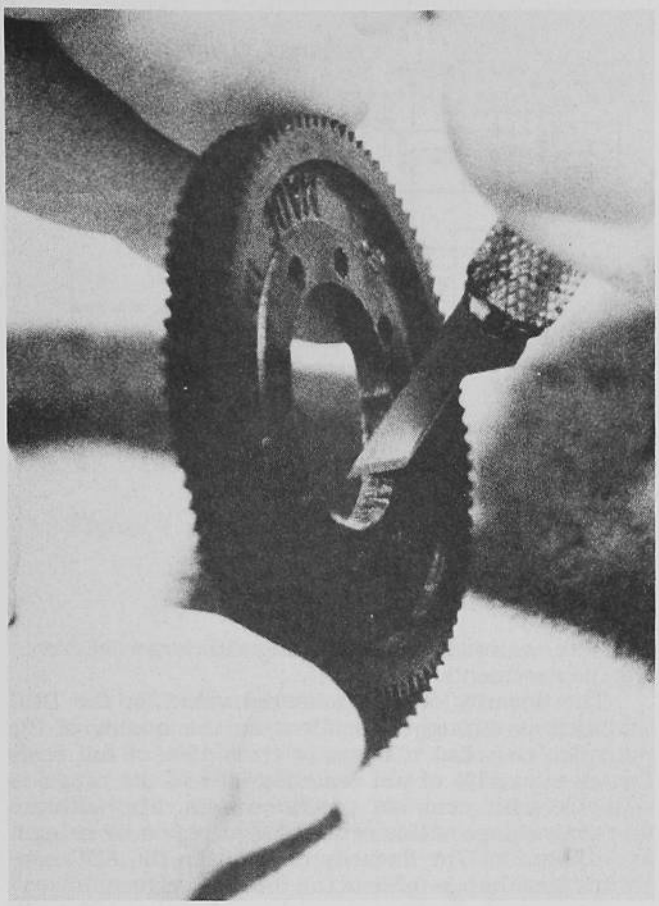


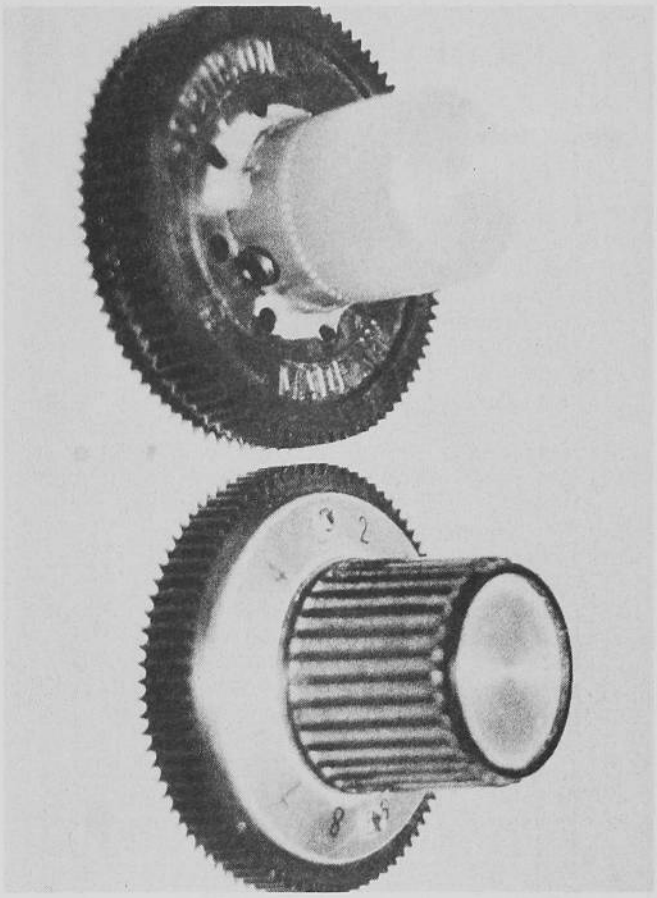
*To prepare a potentimeter for use as the declination axis position sensor, remove the metal cap, cut the plastic stop on the wiper assembly, and then fill the terminal gap on the element card with a filled epoxy.*

measured; then the fast and slow frequencies for 250mS command pulses are measured. The calibration procedure can also be used to adjust the RA normal frequency to 60.17Hz with the 20K ohm trimmer potentiometer. (Note: 60.17Hz is the RA synchronous motor frequency for 180 and 360 tooth gears. The 359 tooth gears are driven at 60 Hz.)

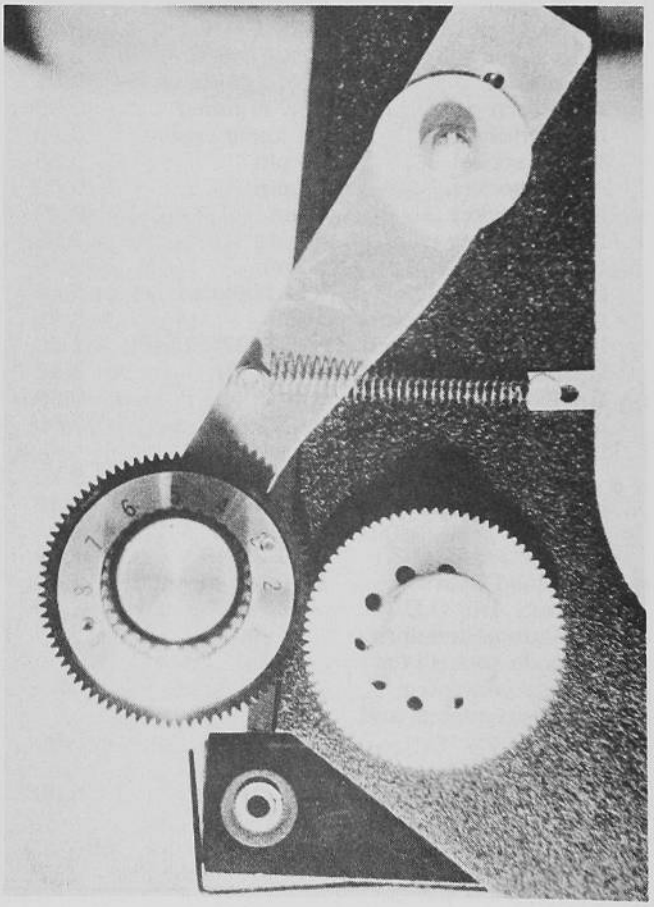
The DEC calibration procedure determines how many 58mS-pulses are required to drive the potentiometer through one fourth of its range. Errors of phasing will be detected in the DEC calibration step. The program expects to drive the ADC from a high to low ADC count for the first pass. If the count starts to increase, the ground and +5V connections are reversed.

The PEC acquire mode starts immediately upon selection, but the first ten seconds (TD) are not used as correction data. This gives the user a short period to align the guide star. Drift data is acquired for the next 490 seconds and is graphed on the screen. Next, the open-loop drive commands are calculated. The commands are drawn over the initial eight-minute cycle error data to reassure the user that the system is functioning. This plot may be skewed from the data if the RA normal frequency was not set to 60.17 Hz. However, the system will correct for the error in the RA frequency. Drift correction can continue for up to 1.5 hours but the data display truncates at one hour.





*To mount gears on the declination slow-motion control knob and potentiometer, bore the gear and clean out a neat hole and them cement them to the two knobs. Mount the potentiometer on a spring-loaded arm.*



At the end of the guide, the user can continue with another guided exposer of the same object or exit the correction routine by pressing the F1 function key. The command sequence is terminated and the data is stored in a file named log.dat. The data file contains the RA integral count alternating with the DEC ADC data count. This operation is automatic and it overwrites the previous file by this name.

**Design Considerations**

This section is provided for additional understanding of the circuit and its limitations. It is a group of short notes which provide some insight into the operation of the system. It is impossible to design a circuit which functions for all combinations of hardware. Thus, this section should help amateurs in adapting the system to other hardware.

The DEC slow-motion control circuit can only provide about 150mA of peak current. This current may not be adequate for some slow-motion control motors. The DEC motor can be tested by placing a 100 ohm series resistor in line with a 12 VDC source and connecting the motor to it. If the motor runs close to a normal rate, it will probably work with the driver. The software is set to pulse the DEC motor for:

DECCNT * 4.17 ms = 58ms per command.

This moves the Meade DEC slow-motion control about 1 arcsecond. We found this value reduced a tendenc to

# List of Parts Required

| Qty. | Item | Description | Price |
|---|---|---|---|
| 3 | Four bit counter | 74LS161 | $ 0.49 |
| 1 | Decade counter | 74LS162 | 0.49 |
| 2 | Quad two-in MUX | 74LS157 | 0.45 |
| 1 | 14-stage counter | 4060 | 0.65 |
| 1 | Hex Inverter | 74LS14 | 0.49 |
| 1 | Dual-D Flip-Flop | 74LS74 | 0.35 |
| 1 | Timer | 555 | 0.35 |
| 1 | Dual Timer | 556 | 0.35 |
| 1 | 5V regulator | 7805T | 0.49 |
| 1 | Heat Sink | TO-220 | 0.45 |
| 1 | 8-bit ADC | ADC0804 | 3.25 |
| 1 | UART | AY-3-1015D | 4.95 |
| 1 | NPN transistor | 2N2222A | 0.29 |
| 11 | Diodes | 1N914 | 0.07 |
| 1 | Crystal | 2.4576MHz | 1.95 |
| 11 | Ceramic Capacitor | 0.1uF 50V | 0.12 |
| 1 | Film Capacitor | 0.1uF 100V | 0.19 |
| 2 | Ceramic Capacitor | 47pF 50V | 0.10 |
| 1 | Ceramic Capacitor | 220pF 50V | 0.10 |
| 1 | Electrolytic | 470uF 15V | 0.29 |
| 1 | Electrolytic | 22uF 15V | 0.16 |
| 1 | Tantalum Cap | 10µF 15V | 0.69 |
| 3 | Resistor | 22 Ohm 1/2W | 0.07 |
| 1 | Resistor | 330 Ohm 1/4W | 0.07 |
| 5 | Resistor | 1K 1/4W | 0.07 |
| 2 | Resistor | 2.2K 1/4W | 0.07 |
| 8 | Resistor | 4.7K 1/4W | 0.07 |
| 2 | Resistor | 10K 1/4W | 0.07 |
| 2 | Resistor | 22K 1/4W | 0.07 |
| 3 | Resistor | 47K 1/4W | 0.07 |
| 1 | Resistor | 10M 1/4W | 0.07 |
| 1 | 15 turn pot. | 50K Trimmer | 0.99 |
| 1 | Potentiometer | 5K linear taper | 0.99 |
| 3 | WW socket | 14 pin | 0.65 |
| 7 | WW socket | 16 pin | 0.69 |
| 1 | WW socket | 8 pin | 0.49 |
| 1 | WW socket | 40 pin | 1.89 |
| 1 | WW socket | 20 pin | 0.99 |
| 1 | WW terminal | T44 100pcs | 3.49 |
| 1 | Kynar Wrap Wire | 100ft | 3.95 |
| 4 | Momentary Switch | SPDT (275-1549) | 2.59 |
| 1 | Shielded Cable 30ft. | (278-752) | 3.49 |
| 1 | DIN Plug | 6 position | 0.89 |
| 1 | 20ft. 28AWG flt rbn | 9-con | 3.00 |
| 1 | card 4.5 x 6.5; punched holes | | 2.75 |
| 1 | Metal Box 2 x 8 x 6" | (270-272) | 8.48 |
| 1 | Plastic Box 1.2 x 2 x 4" | (270-220) | 1.79 |
| 2 | Molded Gears | 85-tooth 48-pitch | 3.00 |
| 1 | Knob, 1.5" O.D | | 1.00 |
| N | D-sub connectors, hoods sockets for hand controller, potentiometer, and computer. | | 5.00 |
| N | Misc. glue, screws, etc. | | 5.00 |
| | Total | | $90.00 |

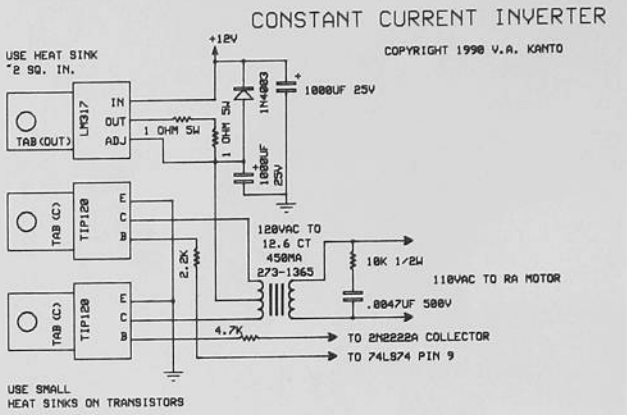



**Figure 5**

fight the controller during guiding with larger DEC control displacements.

The linearity of the measured value for the DEC deviation is strongly dependent on the quality of the potentiometer, but a linearity error ±5% of full scale (better than ±1% of full scale for 90% of the range) is available with common potentiometers. The software takes advantage of this central linear region by using it for calibration. The linearity errors from the ADC contribute less than ±–0.5% of the full scale error.

The synchronous motor drive for the 180-tooth gear operates at about 60.167 Hertz and integral counting over an hour adds up to 216,601 counts. An eighteen-bit binary counter would be required for just one hour of tracking. This problem was eliminated by counting in software which has a 24-bit binary mantissa for floating-point numbers. Because the RA integral counter updates its eight-bit parallel output at unknown intervals, it is not always possible to read the data at the required interval. The interval is extended to the end of the RA clock edge to prevent corrupting data. For the counting interval, the RA readings have an uncertainty error of one count which is equivalent to 0.25 arcseconds.

The operating frequency range for RA motors can vary so a conservative range of 60±–10 Hz was selected. The RA speed is generated by a simple resistor and capacitor voltage-controlled oscillator (555 timer). Inexpensive timing elements such as carbon-film resistors and metallized-film polyester (Mylar) capacitors will result in an undesirable frequency drift over large ambient temperature variations. Because we anticipate only small temperature variations over a usage time of one hour or less, and because the data-acquisition portion of the circuit is capable of self-calibration, inexpensive components are acceptable.

The pulse width of the RA frequency shift limits the slewing capability of the system. With the value of RACNT set to 60, the minimum frequency shift measures 1.78 Hz. A single RA clock count corresponds to about 0.25 arcseconds of movement. Thus, the slew rate is set to:

1.78 * 0.25 = 0.445 arcseconds per second.

Assuming a sinusoidal type of periodic error, the maxi-

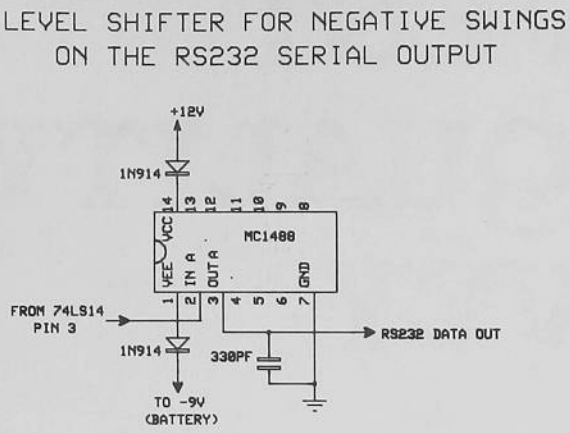



**Figure 6**

mum peak-to-peak correction over an 8-minute interval is:

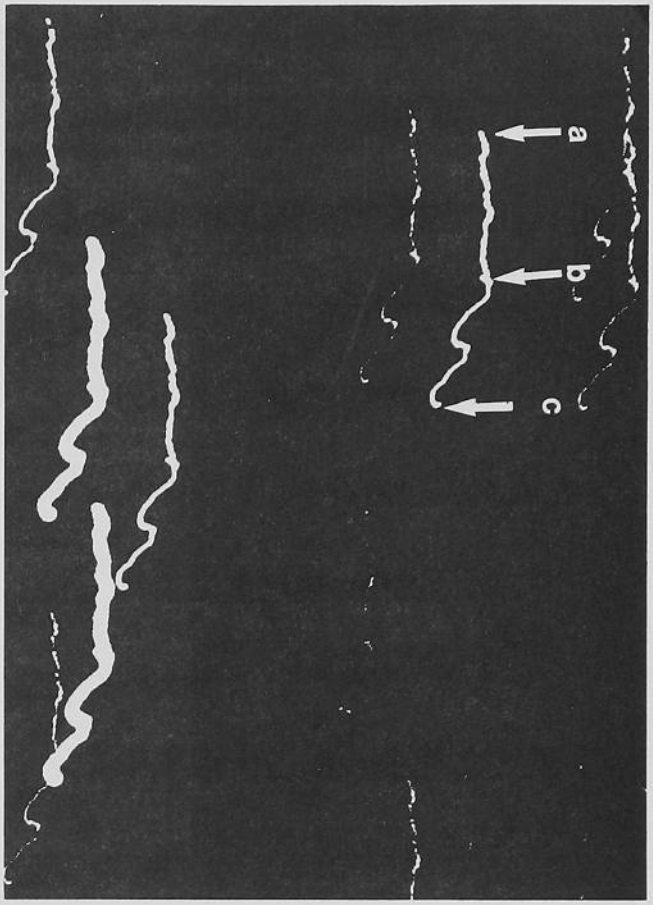
(.445 * 8 min * 60 sec) / PI = 68 arcsec.

The maximum correction for 360 or 359 tooth gears (4 min. period) is half that large. The value of RACNT can be increased to around 200 which increases the correctable gear error to about 227 arc seconds peak to peak. However, we advise caution in increasing the sum RACNT + DECCNT past 217. A total count of 240 consumes the total data interval of one second; plus the program requires some time for housekeeping.

Meade has integrated the voltage inverter into the telescope but this is not true of many synchronous motor drives; they generally run from household power. It is possible to convert the RA clock to 110VAC with the circuit shown in Figure 5, but the 12-volt supply must provide at least 725mA of current. The circuit is not efficient, but it is very simple.

Power for the system can come from a variety of sources. The PEC electronics without the inverter draws about 125mA. The regulated 12V required can be obtained from the Meade jack. It is possible to use a non-regulated supply to operate the circuitry with the inverter. A DC power pack that provides 11 to 13 VDC under load (725mA) will provide proper operation. I have used an old Atari 9.3VDC 1.95A power pack to operate the inverter plus the data acquisition system. The output voltage is 12.5V with about a half of volt of ripple.

The RS232 serial interface circuit was designed using two remaining inverter gates. Although this simplifies the circuit, it may cause compatibility problems with some computers. The serial output line can only swing from zero to about 5 volts. Most computers have the serial threshold voltage set to around 1.5V and they are compatible with logic-level drives. Unfortunately, some computer serial interfaces have the threshold set at a negative voltage. To get negative swings, the inverter driver must be replaced with a line driver. Figure 6 shows the required modifications. The serial communications is set for 2400 baud, eight data bits, no parity, and one stop bit. Since the serial data rate is fixed by the clock frequency (about 4.13ms per data byte), the PWM timing commands are multiples of this interval.




*This photograph proves the performance of the PEC; it shows the unit turned on (from a to b) and turned off off (from b to c). Note that the periodic error is absent between a and b, but quite evident with the PEC off.*

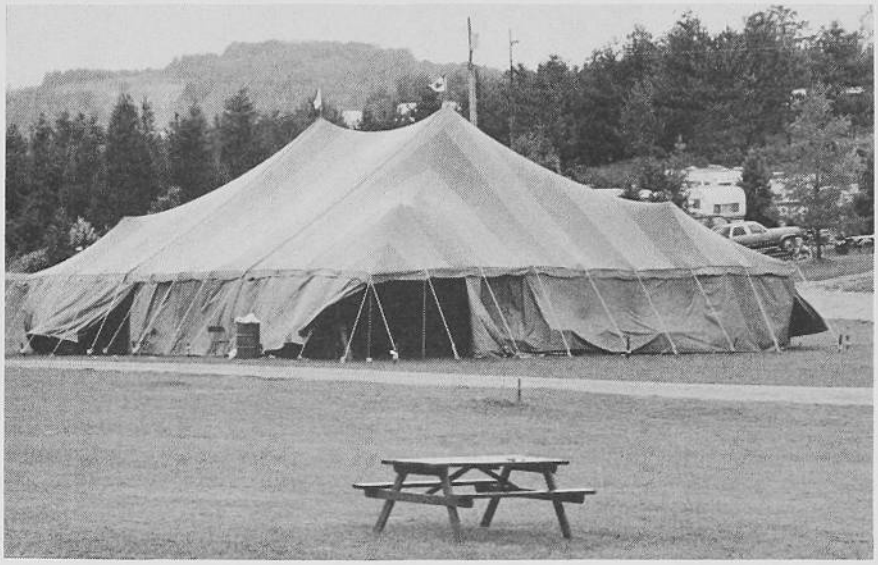
**Ending Comments**

The synchronous motor drive is far from obsolete. Its main disadvantages are power consumption and the high drive voltage. The advantages of synchronous motors are their low cost, their smooth rotation, and their ability to act both as sensor and driver. The method of periodic error correction described in this article is not restricted to the Meade synchronous motor drive. The reader is encouraged to improve upon the method and to enhance the skeleton program.

Viekko Kanto, BSEE, MSEE
and J.E. Munger, BA, BSEE
2924 W. Yorkshire St.
Tucson, AZ 85741

Note: The control program PECV2.BAS is too long to reproduce in *Telescope Making* at any reasonable size. To obtain a copy please send a stamped, self-addressed envelope to the authors or to *Telescope Making* for a printout of the program, or a formatted 360K 5.25" PC diskette in a self-addressed, stamped diskette mailer for a machine-readable copy. The program will be available from *Telescope Making* until March 15, 1992.

# STARFEST OPTICAL QUALITY SURVEY



*At the North York Astronomical Association's Starfest '90 meeting, under a tent, amateur astronomers tested telescopes by autocollimation.*

The quality of commercial optics is one of the hottest topics in astronomy today. What level of precision is required to give satisfactory results for various types of astronomical uses? Can the average amateur astronomer distinguish good optics from poor? What is the state of commercial optics?

In keeping with the interests of amateurs, the North York Astronomical Association attempted to address these questions by conducting an optical quality survey at their annual observing convention. STARFEST '90 was held August 17-19 at the River Place campground near Mount Forest, Ontario. It attracted over 275 astronomy enthusiasts from Ontario and neighboring states.

The optical survey was conducted in two parts. During the Saturday afternoon tent talks, Terrence Dickinson, Peter Ceravolo, and Andreas Gada made presentations on this topic. Terrence gave some guidelines for visually assessing the quality of optics based on what experienced observers, using good optics, have been able to see. Peter described the optician's approach to assessing optical quality and showed some test results. Andreas outlined how the survey would be conducted and walked the audience through the questionnaire as they filled it in.

The intent of the questionnaire was to collect information about the telescope (size, type, when purchased, etc.), the observer (experience, type of observing done), and the observer's perception of the optical quality of his telescope.

By correlating this information with the results of optical testing, the organizers hoped to gain some insight into how telescope users judge optical quality. The testing was conducted that evening.

After speaker David Levy completed his talk, dozens of amateur astronomers scurried to their campsites and eagerly returned to the main tent with their telescopes. The meeting now took on a different appearance — that of an optician's waiting room — as telescope owners cradled instruments.

**Testing**

Testing consisted of the Ronchi and Foucault tests in autocollimation against an optical flat. At the front of the tent stood an optical bench bearing a 17-inch optical flat, an assortment of V-blocks for holding telescopes, and a Ronchi tester. So that everyone could see what Peter saw, a closed-circuit television system stood at ready.

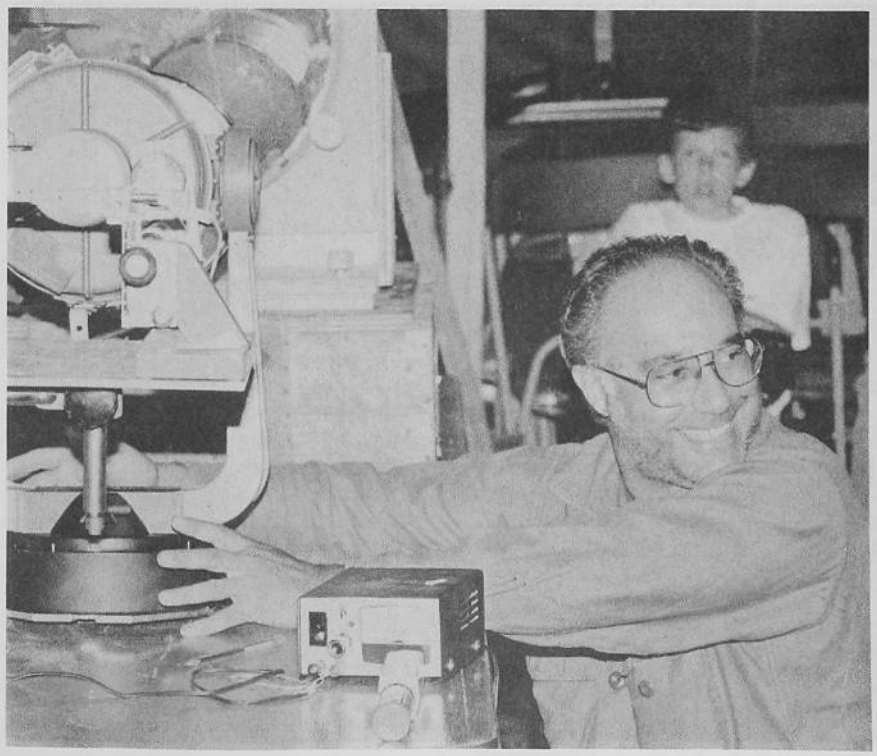
Expectations ran high. What would the tests show? Were we about to witness a parade of optical winners, or would the telescopes brought so proudly for testing go down in flames? The crowd watched restlessly, and murmers and whispers swept through the tent.

The first telescope was an 8-inch Meade. The owner placed it on the optical bench, and Peter aligned the Ronchi grating. After scrutinizing the image, Peter moved a video camera into place. The crowd fell silent as the first image appeared on the screen.

Peter walked over to the monitor and pointed out the features on the Ronchi bands that formed the basis for his remarks. The sensitivity of the double-pass autocollimated Ronchi test was good enough that everyone could see the features as Peter discussed them.

Everyone could see the roughness in the figure and the zonal errors on the television screen. Peter explained that these errors were not desirable, but they weren't severe in

*Tension — and relief! As each telescope took its turn on the test stand, its owner knew that the optical moment of truth had arrived.*

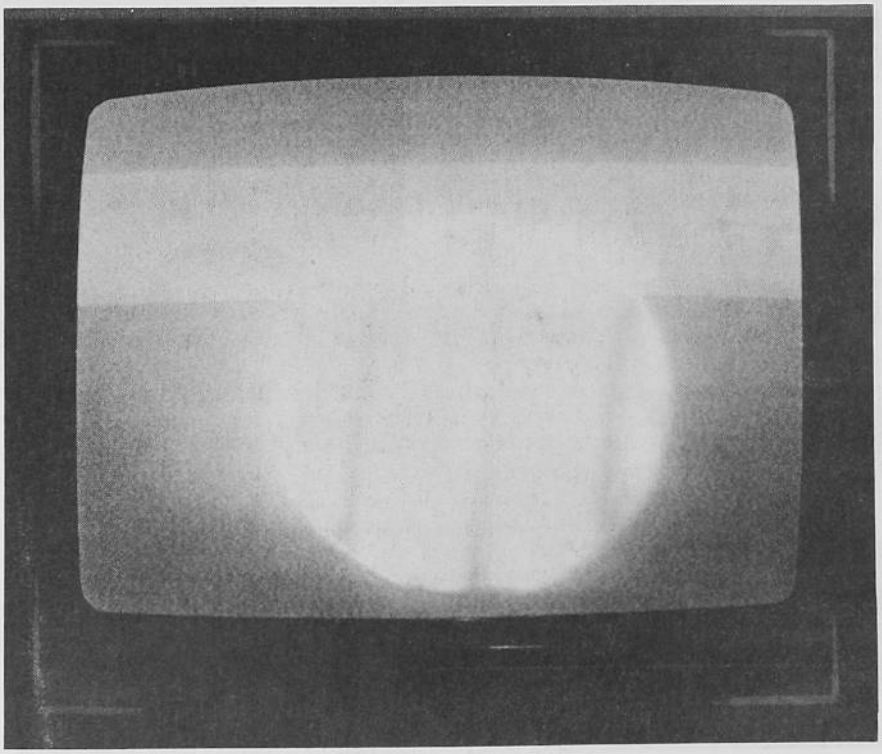


this telescope. He pronounced the 8-inch Meade "acceptable."

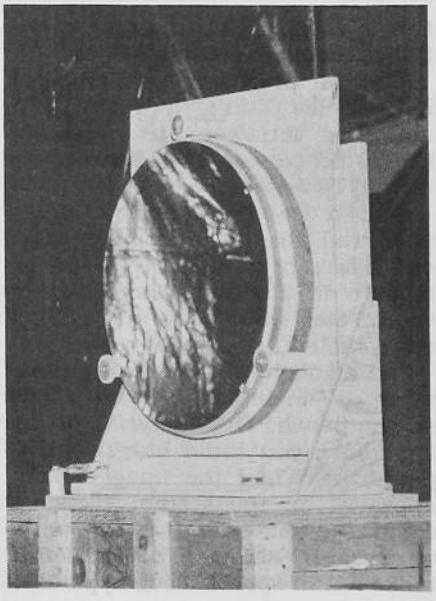
The test procedure was repeated many times during the night. In a marathon four-hour test session, the audience saw 22 telescopes on the big TV screen.

After a few telescopes the audience was able to distinguish good optics from poor. They began to participate in the tests, anticipating what Peter would say and calling out comments of their own.

The highlight of the evening came when a 7-inch Starfire was placed on the bench. The atmosphere was incredible; you could have heard a pin drop! When the image finally appeared on the screen, everyone could see that the Ronchi bands were razor sharp. The audience broke out in spontaneous applause,



*It was well past midnight before the last telescope, a Starfire refractor, was tested. Straight Ronchi bands were good news for its owner.*



and Peter pronounced the system "excellent."

Unfortunately not all telescopes proved to be as good as the Starfire. Although they were well corrected overall, the two C14s tested that night were rough and zoned like a giant phonograph record. You could see the disappointment on the faces of the owner and the dealer who had sold the telescope.

The surprise of the evening was an undercorrected Galaxy Optics 10-inch f/4.8 mirror. Spherical aberration and a hump in the center earned that telescope an "unacceptable" rating.

It was not until 2 in the morning that the last telescope was finally tested. The marathon was over. The organizers had shown that optical testing using optical bench testing can be conducted at an amateur meeting. They had shown that an audience could see and, indeed, participate in testing and that a large crowd could learn enough about testing to know good optics from bad. It had been an incredible evening and a first for amateur astronomy.

## SUMMARY OF OPTICAL TEST RESULTS

| Rating | Telescope | Comments |
|---|---|---|
| Superb | 7" Starfire | ronchi bands were razor sharp |
| | 4" Genesis Celestron C70 | overall image was clean |
| | Celestron 5 (two tested) | smooth wave front |
| Good | Cave 6" /f8 | a good wave front |
| | Edmund 6" f/8 | overall good correction |
| | Coulter 8" Odyssey | straight edge |
| | Coulter 10" f/8 | |
| Acceptable | Celestron 8 | edge roll |
| | Meade 8 & 10 SCT | zonal errors roughness |
| | Celestron 90 | a lot of color; curvature not completely corrected |
| Poor | Celestron 14 | severe roughness |
| | Galaxy 10" f/4.8 | a substantial amount of spherical aberration unacceptable undercorrection high in the center of the mirror |
| | Bausch & Lomb 5" f/5 | rough wave front edge roll and zonal errors |
| | Criterion Dynamax 8 | very rough wave front edge roll and zonal errors spherical aberration |

### Results

What conclusions can be drawn from the 44 completed questionnaires (150 were handed out) and the results of the optical testing?

All respondents felt that the optical quality survey was of benefit to the astronomical community.

Two questions on the survey were designed to determine if people wanted standards and how much extra people were willing to pay for certified optics.

All respondents felt that the telescope manufacturers should provide a universal set of standards by which to compare their telescopes.

Six people said zip to the certification question. As one person put it, "This is a cost of business which should be part of quality control. Why should I pay to have the manufacturer certify that he did what he already was supposed to do anyway?"

Five said under $50, but the majority of the 23 respondents said they were willing to pay an extra $51 to $500 for certified optics. Three were willing to pay between $501 and $1000, while two were willing to pay over $1000 if "certification was independently done and not done by the manufacturer, and as long as the optics were certified as good or excellent."

The survey asked how users rated their own telescope, first, in order to determine if the average observer could distinguish good optics from poor and, second, to identify what level of precision is required for various types of astronomical uses. Their question was — "Based on your experience, how satisfied are you with the overall optical performance of your telescope? Please explain why you answered the way you did."

Based on the nine telescopes tested for which there was correlating data, these are the results: Six out of the nine respondents indicated that they noticed some type of image degradation: they could not get sharp planetary images; they were not able to bring stars to a sharp focus; or the images looked pretty good but their telescopes were rated as acceptable or poor during the optical test. One person said he "got nice tight star images, even under high power." Yet his telescope was rated as poor. The remaining two respondents said they got good stellar and planetary images. There scopes had been rated as superb.

Based on these results one can conclude that the average amateur can distinguish good optics from poor. In addition, that optics free of defects (those rated as being superb) are required for detailed planetary observing. Astrophotography on the other hand is a lot more forgiving. The Dynamax 8, the worst scope tested, has been used for years by Mike DeVillair to do some exquisite deep sky photography. What level of precision is required for deep sky work could not be determined based on the limited data. Future investigation is required.

What happens next depends on you. The organizers are preparing a comprehensive report reporting what they did, how they did it, and what their findings were in depth. This report will be sent to members of TOMA for review and comment. They would like other groups to conduct the same type of survey to expand on the work they have started. They would like to see TOMA take an active part in these surveys and involve the astronomical community, their customers, in the development of standards.

Andreas Gada, President
N.Y.A.A.
26 Chryessa Ave.
Toronto, Ontario M6N 4T5

# Letters

require no more advice on the subject.

Fabrication or purchase of a quality full-aperture test flat consumes considerably greater time and money than the fabrication of a suitable Ross lens does. As an example, when I set up a Ross test for an 8-inch f/4.5 paraboloid, I was able to purchase the 200mm focal-length plano-convex lens I needed for the job from Edmund Scientific. Test plate matches done on the delivered lens showed that over the portion of the aperture I used, the lens was smooth on both sides to at least 1/8-wave. The best part: the lens cost only $14.70!

I think that the amateur community would benefit more from commentary informed by experience and confirmed by theory than from the other way around. Many times, I have seen theoretical considerations used to justify criticism of a method that would work just fine when tried by someone who hadn't read the theory.

Scott Milligan
843 Boston Road
Groton, MA 01450

**Quick-Release Tube Clamps**

Richard/Your readers will probably be interested in a simple tube-clamping device I built. The levers you see in the picture and diagram are quick-release bolts used on mountain bikes to allow adjustment of seat height. (You set the seat high while going up hill, low while heading down.)

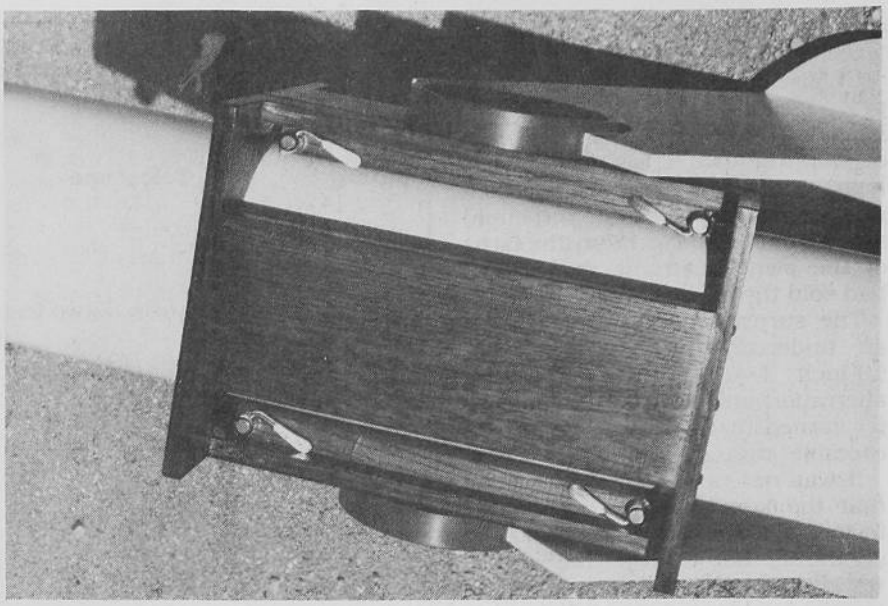
I would think that someone else has considered this idea, but several people here in Tucson, many who frequent the RTMC, say they've not seen it done. The clamps bring the two halves of the tube cradle together. When the clamps are loosened, compression springs opposing the clamping force assure that the cradle releases its grip on the tube.

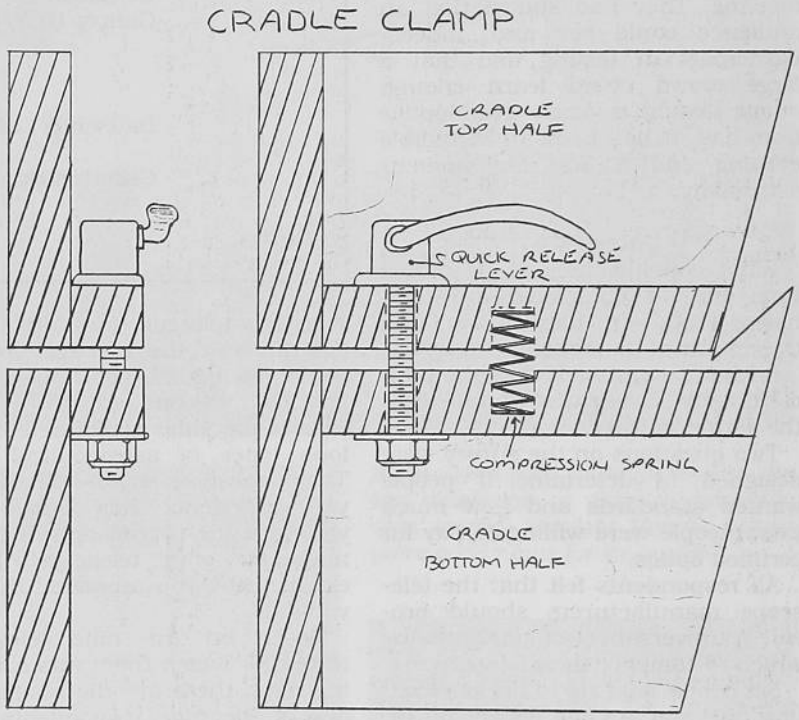
Though shown in a Dobsonian configuration, the cradle was designed for use in a fork mounting. I intend to make the forks from fiberglass wrapped foam. I'd like to hear from anyone using this type of construction for telescope mounts.

Andrew J. Meyer
3100 W. Utah Street
Tucson, AZ 85746

**Stripping Old Aluminum**

Richard/ Because I do a considerable amount of mirror refiguring, it is important that I have an easy way to strip the old coating. I had been using sodium hydroxide, which takes hours sometimes and needs to be warm to work. This can also be quite dangerous to your health if it's done indoors. The last mirror I stripped was a 13.1-incher and it took almost 24 hours.






I talked to our coating engineer at work and he recommended PCB Etchant Solution from Radio Shack. This chemical is used for making PC boards. It will not harm the glass, does not need to be heated, and stripping can be done without the windows open. The best way is to submerge the mirror in the solution, but since I usually do large mirrors, I merely pour the solution on the mirror and spread it around with a paintbrush. The solution must sit on the surface for 5 to 10 minutes to work. To strip a mirror of this size takes about 30 minutes, moving the solution around every 5 minutes or so. The price of this solution is about $3.00.

Richard J. Wessling
5429 Overlook Drive
Milford, OH 45150

**Cheap Lyot Or Fancy Foucault?**

Dear Richard/ Recently I found that if you remove the metal knife-edge from an ordinary Foucault tester and use in its place an unmounted red glass filter, the resulting Foucault image will appear on a red background as if the mirror were made of molten glass. Also, if you advance your new "knife-edge" just until the face of the mirror turns entirely red, the mirror will show a multitude of small black irregularities that look very much like the microripple seen in the Lyot test (Tex-

ereau, second edition, page 62, figure 29d). I believe that this is because the filter acts as a Lyot-type phase-delay element. Have we here an inexpensive version (see *TM#28*, page 30) of the famous but unavailable Lyot test? Or just a fancy Foucault test?

Herbert Highstone
P. O. Box 249
Monte Rio, CA 95462

*— I tried the "Highstone test" and it's beautiful. What you've got is a sexy version of the Foucault test. The black ripples are shadows generated by the opaque parts of the edge of the filter. (You can verify this by opaquing the edge and watching the black ripples go away. You then have the wire test.)*

*Because the whole mirror surface is visible, this test is easier on the eyes (and brain) than the Foucault test, and the diffraction effects from the knife-edge are less confusing. I'd hate to try explaining what's going on to a novice.*

*For a neat variation, replace the knife-edge with two thin acetate filters butt-spliced together. If you use a red and blue filter, for example, you'll see "positive" and "negative" Foucault images in red and blue side by side. Trim the filters with a razor knife and apply a drop of plexiglass cement to bond them. Wratten filters work well. — RLB*

**Is Quarter-Wave Good Enough?**

Richard/I've been flipping through old issues of *TM* and came across a letter from Mladen Vranjican (*TM#34*) regarding the accuracy of testing optical systems with a star and Ronchi grating. I have used this test prior to aluminizing as a final check on my "finished" mirrors and was therefore interested in its ultimate sensitivity.

In mid-1987, I made an 8-inch f/10 mirror, and while it was still spherical, I performed a Ronchi star test on it. A spherical mirror of this size and focal ratio is not quite 1/4-wave.

Could I detect the error? The answer was an unequivocal YES. The Ronchi lines were not straight — even a knife-edge showed shading.

The mirror was then parabolized and tested in a double-pass autocollimation setup until a knife edge showed a clean "null." A Ronchi star test then showed straight lines, as one would expect. While I can't answer Mr. Vranjican's question about the smallest error one can detect, I feel confident in stating that an experienced TM in reasonable seeing could detect 1/8-wave errors. If anyone has doubts they should try it; making a spherical mirror is quite easy.

On another topic: in a letter published in *TM#22*, Ziljho Andreic suggested that bubble-wrap plastic might make a suitable floatation cell for thin mirrors. Some time before this letter appeared, I had suggested to a friend that he try it for a 12-inch, f/6 thin mirror he had difficulty in mounting.

Anyway, he did it and it worked very well. I suspect that the production techniques used result in each cell's being almost equally inflated and the load spread over many cells, with minor differences cancelling out.

Steven Lee
"Rainbow"
Timor Road
Coonabarabran, 2357
Australia

*— My own experience and computer modelling of the diffraction image in and out of focus suggest that 1/8-wave of spherical aberration significantly alters the out-of-focus diffraction image, but that the in-focus image remains more-or-less undisturbed until the aberration is 1/4-wave.*

*Peter Ceravolo recently made a set of mirrors of the same aperture and focal ratio, but with 1-wave, 1/2-wave, 1/4-wave, and 1/10-wave of spherical abberration. Experienced observers had difficulty distinguishing between 1/4-wave and 1/10-wave mirrors, but the 1/2-wave and 1-wave mirrors performed poorly.*

*As Dick Suiter has repeatedly taken pains to point out, the out-of-focus star test is exquisitely sensitive, far more sensitive than in-focus testing. Star testing is especially sensitive to errors in the extreme outer zones of the mirror, where Foucault and Ronchi testing are least sensitive. Star testing makes an excellent check on the others, and as HST has shown, checking lab tests is a good idea.*

*I'm glad that bubble-wrap seems to work; I suppose it's the same as Ritchey's beloved "Brussels carpet." If a bubble-wrap-mounted mirror performs poorly, the first thing I'd do is put in a new piece of bubble-wrap. I'd also watch for degrading performance, because the bubbles sometimes leak.— RLB*

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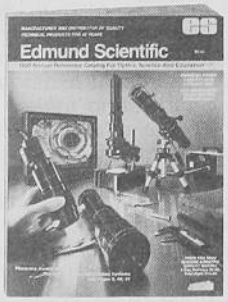


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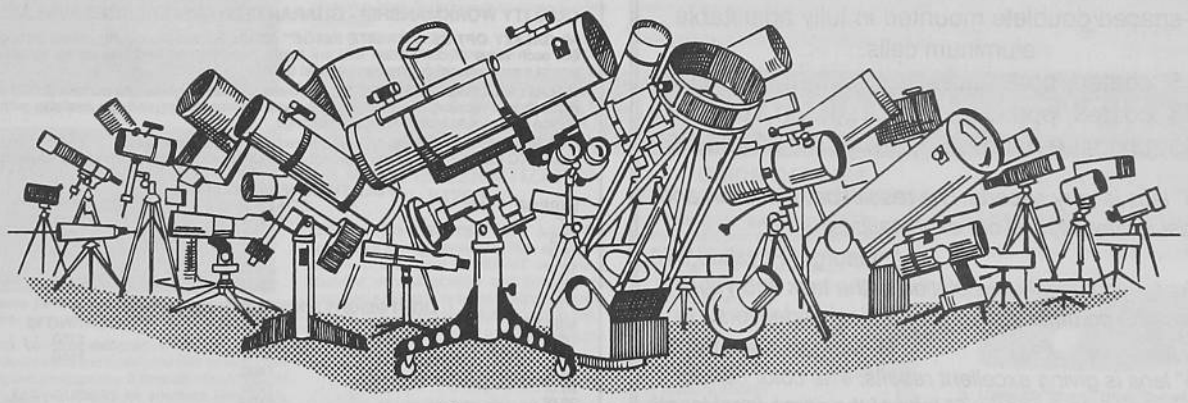

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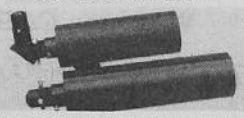

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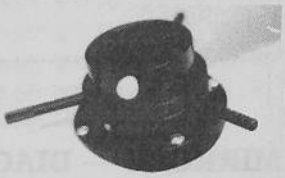

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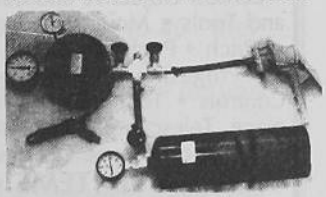

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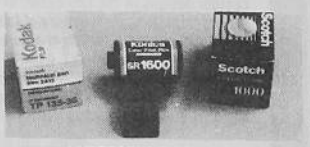


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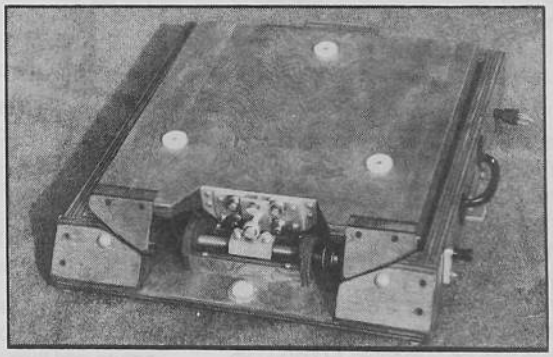

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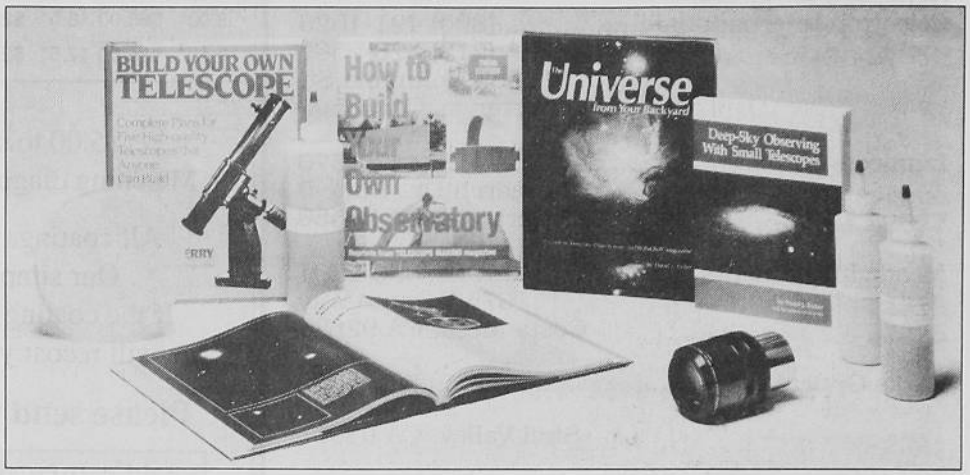


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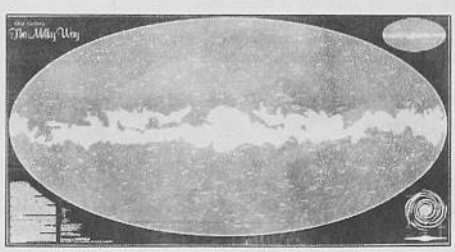


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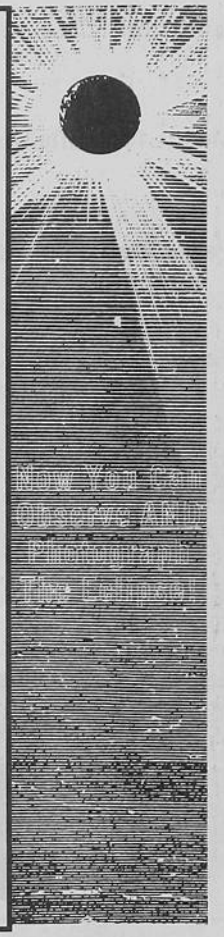

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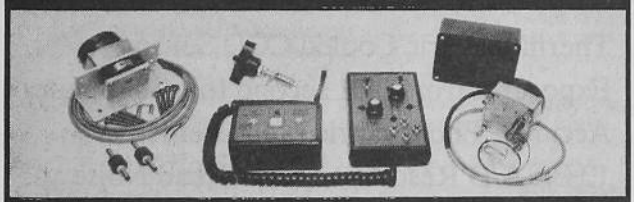

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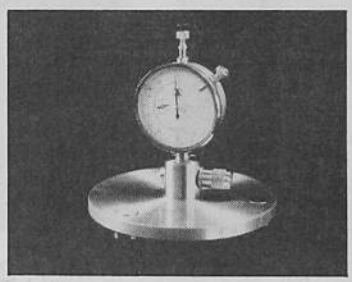

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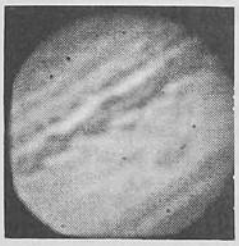

Jupiter, 20" f/30

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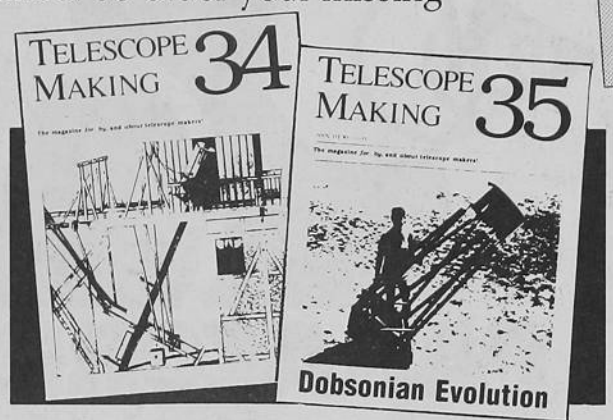


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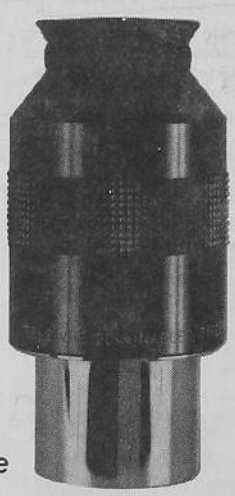

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